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Indian Standard

METHODS OF MEASUREMENTS FOR ELECTRON TUBES — RECEIVING AND TRANSMITTING TUBES

(First Revision)

UDC 621·387·362 : 621·317·3

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NEW DELHI 110002

Gr 12

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Indian Standard

METHODS OF MEASUREMENTS FOR ELECTRON TUBES — RECEIVING AND TRANSMITTING TUBES

(*First Revision*)

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(*Continued on page* 2)

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Indian Standard

METHODS OF MEASUREMENTS FOR ELECTRON TUBES — RECEIVING AND TRANSMITTING TUBES

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 15 October 1981, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard deals with the methods of measurements of the important characteristics of electron tubes of the receiving and transmitting types.

0.3 This standard was originally published in 1967. The revision has been undertaken to include methods of measurements for transmitting tubes also.

0.4 While preparing this standard, assistance has been derived from the following documents:

ASA C 60. 15-1963 Method of testing electron tubes. American Standards Association.

IEC publication 151 Measurements of the electrical properties of electronic tubes and valves. International Electrotechnical Commission.

JSS 51500 (Part II) Test methods for electron tubes. Ministry of Defence.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

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*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard deals with the methods of measurements of the characteristics of electron tubes of the receiving and transmitting types.

2. TERMINOLOGY

2.0 For the purpose of this standard, the definitions given in IS: 1885 (Part IV/Sec 1)-1973* shall apply.

3. GENERAL TEST CONDITIONS

3.1 Except when the nature of a test calls for varying or abnormal conditions, all tests should be made at the normal rated conditions specified in relevant Indian Standard or as specified by the manufacturer. If the manufacturer's rating is not specific, test conditions not specified should be selected in accordance with the best judgement of the testing authority and should be clearly and fully stated as a part of the test data. In general, measurements should be made after the tube has attained temperature equilibrium at the stated test conditions.

3.2 When a filament or heater is rated in both voltage and current, the rated voltage should be employed in tests. When filaments or heaters are to be used in series, the rated current may be employed, but this condition of measurement is to be stated as a part of the test data. Direct current should be used for filament heating, except where the normal operating condition is with alternating current heating, in which case the use of the latter should be stated. When dc heating is employed, the negative filament terminal should be taken as the datum of potential. When ac heating is employed for filamentary cathode, the midpoint (that is the centre tap on the filament transformer secondary, or the midpoint on a resistor shunting the filament) should be taken as the datum. In the case of indirectly heated equipotential cathodes, the cathode is taken as datum of potential.

3.3 When measuring heater or filament voltage the voltmeter should be connected to the tube pins or terminals. This is of particular importance with large tubes in which the filament current is often considerable and appreciable error arising from the voltage drop in the filament supply leads may result if the filament voltage is measured at, for example, the supply source. The voltmeter could also be connected to the socket terminations as other terminations intended to connect the tube pins or terminals to an external circuit, provided the voltage drop between the tube pins or terminals and these terminations is negligible.

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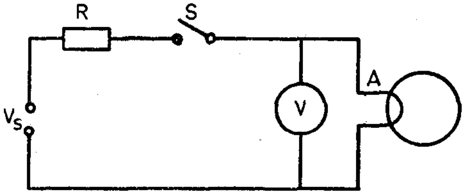
*Electrotechnical vocabulary: Part IV Electron tubes, Section 1 Common terms (*first revision*).

4. METHODS OF MEASUREMENT

4.1 Heater Warm-up Time

4.1.1 The circuit for measuring heater warm-up time is shown in Fig. 1.



A — Heater of the tube under test
R — Series resistor
V — Voltmeter measuring heater terminal voltage
V_S — Source voltage (dc or ac)

FIG. 1 CIRCUIT FOR THE MEASUREMENT OF HEATER WARM-UP TIME

The source voltage V_S and the series resistance R shall be adjusted to the values given by the following formulae:

$$V_s = 4 \, V_f$$
$$R = 3 \, (V_f / I_f)$$

where V_f and I_f are the nominal heater voltage and current respectively. The switch S is closed and the time taken for the heater terminal voltage, V, to attain 0·8 times its nominal value, is measured.

4.1.2 *Precautions*

4.1.2.1 *Temperature before the measurement* — In order that every part of the tube should be at room temperature, no voltage should be applied to the heater for a period of at least 1 hour prior to the measurement.

4.1.2.2 *Source impedance* — The internal resistance of the heater supply source should be negligible compared with the value R, of the series resistor.

4.1.2.3 *Indicating instrument* — The internal resistance of the voltmeter should be high compared with the resistance of the heater when hot.

4.1.2.4 *Series resistor* — Resistance R should be within 1 percent of its theoretical value.

4.2 Cathode Heating Time — The cathode heating time is the time required for the cathode current to attain a specified value (for example, one fourth of the nominal value) with stated electrode supply voltages applied and with stated impedance in the electrode circuits (*see* Fig. 2).

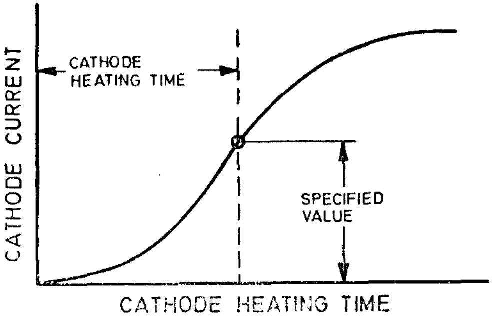


FIG. 2 RELATION BETWEEN CATHODE CURRENT AND TIME

4.2.1 The circuit used for the measurement of cathode heating time is shown in Fig. 3. The supply voltages shall be kept constant during the measurement. The filament circuit is closed and the time is measured from this instant until the instant the indicating instrument shows the specified value.

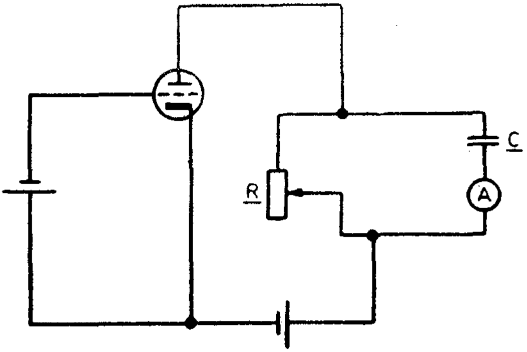


FIG. 3 CIRCUIT ARRANGEMENT FOR MEASURING CATHODE HEATING TIME

4.2.2 *Precautions*

4.2.2.1 *Temperature before the measurement* — In order that every part of the tube should be at room temperature, no voltage should be applied to the heater or filament for a period of at least 1 hour prior to the measurement.

4.2.2.2 *Source impedance* — The internal resistance of the heater or filament supply source should be negligible compared with the resistance of the cold heater or filament.

4.2.2.3 *Indicating instrument* — For acceptable accuracy, it is important that the indicating instrument has low damping characteristics.

4.3 Heater or Filament Current

4.3.1 The specified voltage is applied to the appropriate filament or heater terminals in series with a suitable ammeter. All the other elements are kept floating. The current is measured when equilibrium is reached allowance being made for the voltage drop across the ammeter and for the current drawn by the voltmeter.

4.4 Filament or Heater Heating Characteristic — When tubes are operated with the filament or heaters in series, it is desirable that the voltage be divided during the heating period as nearly as possible in accordance with the rated operating voltage of the individual filaments or heaters, in order to minimize the likelihood of burning out and to ensure minimum heating time of the entire heating circuits. In order to judge the heating characteristic of individual tubes in a series string, the time variation of the filament or heater resistance of each tube should be compared with the average of the entire heating circuits.

4.4.1 Measurements are made in a circuit as shown in Fig. 4 and the resulting data are plotted as percent of rated or final heater resistance against time as in Fig. 5. In Fig. 4, T_1 and T_2 are a variable and a tapped transformer respectively, having ratings adequate to ensure good regulation. Switch S_1 is for energising the complete circuit and combination of switch S_2 and resistor R_m is used to protect the meter A, against excessive initial surges, the resistance R_m being made equal to the impedance of the meter A. Protection against short circuits is afforded by the fuse.

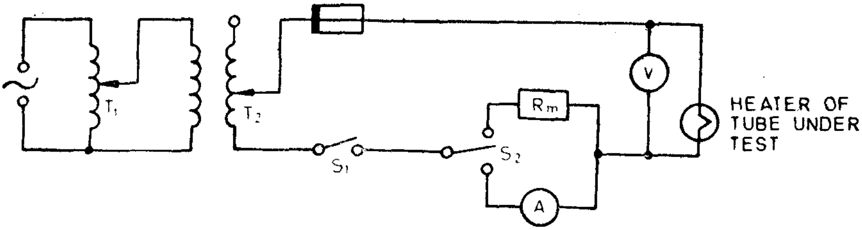


Fig. 4 Circuit Arrangement for Measuring Heater Heating Characteristics

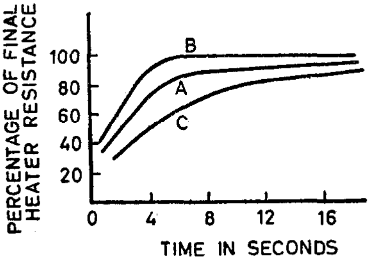


Fig. 5 Curves Showing Percentage of Final Heater Resistance Against Heating Time

4.4.2 The output voltage of T_2 is to be equal to the rated heater voltage of the tube plus the drop through the low-resistance meter A or its equivalent R_m. Readings of current I are taken at known intervals. The percentage of the final resistance attained at the time of any reading will be 100 IR_h, where R_h is obtained from the final heater voltage at rated heater current.

4.4.3 The curves of Fig. 5 show the percentage of final heater resistance plotted against heating time. Curve A may be considered as average of indirectly heated tubes used in series operation, while curves B and C are for heaters having relatively fast and slow heating characteristics respectively (when operated in series with tube having heating characteristics such as given by curve A). It will be noted that a tube such as that having the characteristics of curve B will operate with heater temperature above the final value during part of the heating cycle and the maximum voltage across the heater will exceed the rated value in proportion to the amount by which the curve of percent of final heater resistance against time differs from the average of that characteristics for all values in the circuit. On the other hand, a tube having a characteristic like that of curve C will reach its final temperature more slowly when operated in a series circuit when the average value and the heater voltage will never exceed the rated proportional value.

4.5 Emission Current

4.5.1 *Emission* — To avoid damaging the tube under test, the emission voltage shall be applied only for sufficient time to permit the emission to reach the specified minimum value. The duration of the test shall not exceed 5 seconds. When only a minimum current limit is specified, a voltage less than the value specified may be applied provided the required minimum emission current is thus obtained. In testing of receiving tubes when only a minimum current limit is specified, the test shall be performed by increasing the applied voltage till the specified minimum emission current is obtained and reading the voltage drop across the tube under test.

4.5.1.1 *Emission at reduced filament voltage* — If an emission current test is specified at reduced filament voltage, this test shall be performed prior to the emission current test at rated filament voltage. The tube shall be operated with only 90 percent of rated filament voltage applied. After allowing the cathode temperature to stabilize, the emission voltage shall be applied in the manner specified in **4.5.1**.

4.5.1.2 *Emission at rated filament voltage* — The tube shall be operated with rated filament voltage applied. After allowing the cathode temperature to stabilize, the emission voltage shall be applied in the manner specified in **4.5.1**.

4.5.2 *Peak Emission by Voltage Drop* — The tube shall be tested with the specified voltage applied to the filament or heater, with a 50 Hz anode supply sufficient to start the tube and sufficient series resistance to limit the anode current to the specified maximum current value per anode. A suitable circuit designed to permit the conduction of the specified peak current for one or two approximate half-cycles per second shall be provided. The peak voltage drop exclusive of the starting voltage measured from an anode to the reference point as shown on a cathode ray oscilloscope, or by other suitable means, shall be within the limits specified.

4.5.3 *Peak Emission* — The filament or heater potential shall be applied and the grids, if present, shall be connected to the anode. A suitable capacitor shall be discharged through the tube and a load resistor. The peak current shall be measured by an oscilloscope suitably calibrated. An equivalent method may be used. Pulses shall be applied in such a manner that the tube will not be damaged. The peak current shall be within the limits specified and there shall be no evidence of sparking during the test.

4.5.4 *Emission by Oscillation* — At the end of the power-oscillation test the filament potential shall be reduced until the rf power output has been reduced by 10 percent, at which point the filament potential shall not exceed the value specified, or the filament potential shall be adjusted to the limit value specified, at which point the power output shall be not less than 90 percent of the initial value.

4.5.5 *Pulsing Emission* — Either of the following test methods, **4.5.5.1** or **4.5.5.2**, may be used for this test.

4.5.5.1 *Square wave* — The tube shall be operated at the electrode potentials specified. Where pulse voltages are indicated the pulse duration shall be not less than 2 nor greater than 10 μs. Time of rise shall be not greater than 10 percent of the pulse duration and time constant of fall not greater than 20 percent of the pulse duration. The duty shall be not less than 0·001. Variations in 80 percent of the top portion of the pulse shall not exceed ± 5 percent of the maximum amplitude and no portion shall fall below the maximum amplitude by more than 10 percent. There shall be no sign of arcing during the latter half of the test and the average peak anode current shall be within the limits specified.

4.5.5.2 *Sinusoid* — The tube shall be operated at the electrode potential and conditions specified in the detail specification. A nominal ½ sinusoidal pulse source which meets the following requirements shall be applied. Pulse duration (t_p shall be 2 μs minimum, 10 μs maximum, at the base line of the pulse; pulse repetition rate (prr) shall be not less than 20 pulses per second. There shall be no sign of arcing during the latter half of the test. Excluding any spike the peak diode current, or peak tube drop (whichever is specified), shall meet the specified limits at the required peak pulse value when a stabilized reading is obtained up to a maximum of 1 minute.

4.5.6 *Emission Oscillation* — This test shall be made with the tube operating under the oscillation test conditions after the power oscillation test. The filament potential shall be changed as specified and the change in power output or cathode current shall be within the limits specified.

4.5.7 *Pulse Emission* — The tube shall be tested for pulse emission in the circuit shown in Fig. 6. A resistor shall be substituted for the tube under test for calibration purposes. R_1 R_a and the calibrating resistor (as shown in Fig. 6) shall be within ± 5 percent of that specified in the detail specification and shall be non-inductive. The control grid, and the screen grid when present, shall be tied directly to the anode. The calibrated pulse voltage amplitude shall be within the value specified over 80 percent of the top portion of the pulse and shall not vary from this value by more than 5 percent. The modulator impedance shall be as specified in the detail specification. The pulse voltage characteristics shall be $t_p = 5·0 \pm 0·25$ μs; time of rise $t_r = 0·5$ μs maximum; time of fall $t_f = 1·0$ μs maximum. The pulse emission shall be within the limits specified in the detail specification.

4.6 Static Characteristics

4.6.1 *Introduction* — The static characteristics of an electron tube are valuable as a means of predicting the performance of the tube since load characteristics may usually be computed for assumed circuit conditions. The various tube constants and the perveance may be calculated from families of static characteristics. Load characteristics may be obtained in some cases by actually operating the tube in the desired circuit and making the appropriate measurements.

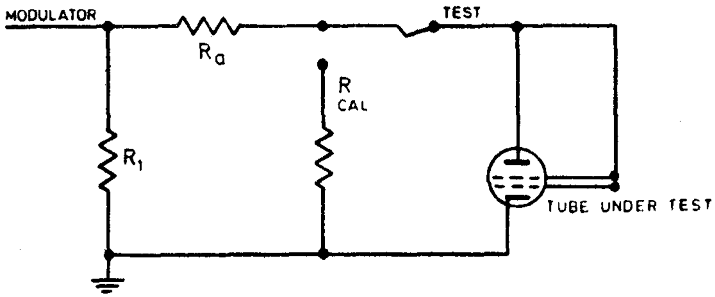


FIG. 6 CIRCUIT FOR TESTING PULES EMISSION

4.6.2 *Static Characteristics of an Electron Tube* — The more useful static characteristics of an electron tube are:

a) Electrode characteristics,
b) Constant-current characteristics, and
c) Transfer characteristics.

4.6.3 *Direct Current Method* — A representative arrangement for the determination of the characteristics of electron tubes is shown in Fig. 7. Although battery supplies are indicated, in actual practice the supplies may be derived from a well-filtered dc source, preferably a regulated power source.

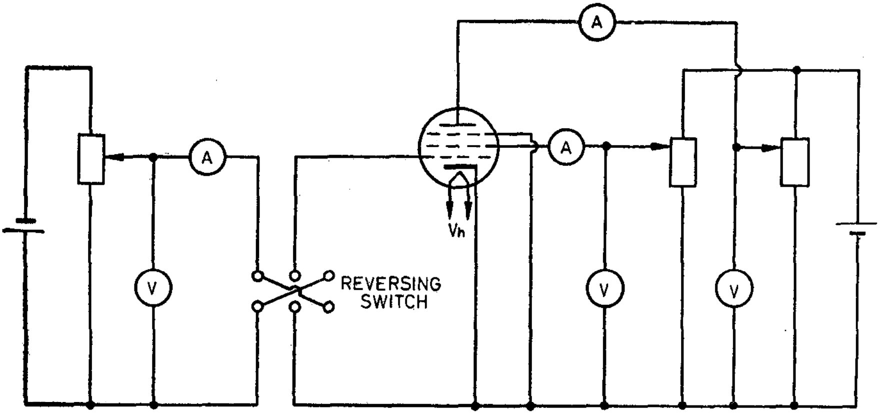
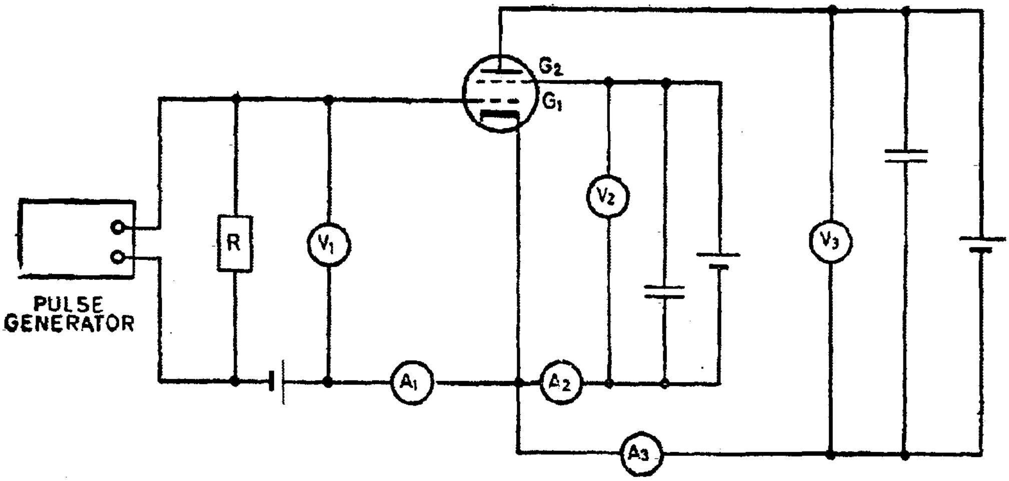


FIG. 7 CIRCUIT ARRANGEMENT FOR MEASURING STATIC CHARACTERISTICS BY DIRECT CURRENT METHOD

4.6.4 *Pulse Method* — It is of considerable importance to know the static characteristics of electron tubes in the region where electrode dissipation may exceed safe values. It is impossible to obtain these characteristics by the conventional direct current methods without damaging the tube. In such cases it is necessary to employ pulse methods in which the tube is allowed to pass current only for short intervals of such duration and frequency so that it is not damaged.

Pulse methods may be employed for obtaining electrode characteristics, transfer characteristics or constant-current characteristics. The basic elements needed for pulse method are the pulse generator and the current and voltage indicators. The point-by-point pulse method consists of applying known pulse voltage to the control grid and simultaneously measuring the corresponding maximum pulse currents to the electrodes under specified test conditions.

The applied voltages are adjusted point-by-point over the desired ranges to obtain a family of characteristic curves. The circuit arrangement for pulse method is shown in Fig. 8.



V_1 = Grid voltage
V_2 = Screen voltage
V_3 = Plate voltage

A_1 = Grid current
A_2 = Screen current
A_3 = Plate current

FIG. 8 CIRCUIT ARRANGEMENT FOR MEASUREMENT OF STATIC CHARACTERISTICS BY PULSE METHOD

4.6.4.1 *Pulse generator* — In the circuit of Fig. 9 the tube may be considered as a pulse amplifier in which any pulse shape applied to the control grid circuit is amplified and applied to the tube under test. This circuit has the advantage of not requiring a specific terminating impedance. Several amplifier tubes may be operated in parallel to provide additional current if precautions usual for parallel operations are observed. Several arrangements of this basic circuit may be used depending on the location of the ground connection and the polarity of the output pulse.

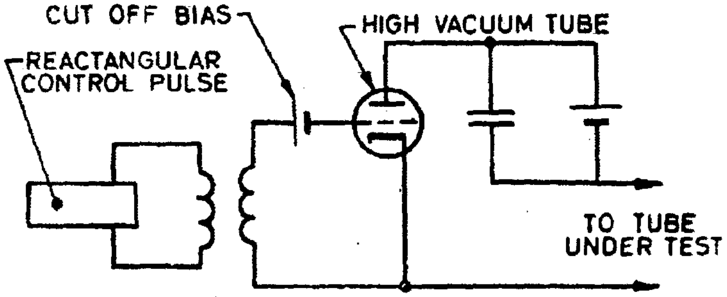


FIG. 9 TUBE AS A PULSE AMPLIFIER

If secondary emission effects in the tube under test introduce a negative impedance, the pulse generator must be shunted with a non-inductive load resistor of such value as to maintain a net positive impedance at its terminals. This resistor R should be located between the generator and the current indicator as shown in Fig. 8.

4.6.4.2 *Peak reading voltage indicator* — Peak reading voltage indicator is useful in measuring the peak value of the pulse voltage applied to an electrode in obtaining vacuum tube characteristics by point-by-point pulse method.

In order to function successfully, the circuit consisting of the capacitory resistor and meter shown in Fig. 10 shall have a time constant that is large with respect to the time interval between successive pulses. The indicator accuracy is greatest with rectangular pulses although good accuracy may be obtained with other pulse shapes if the pulse duration is sufficient.

Where the pulse is substantially square and OFF/ON ratio is known, a moving coil or other averaging instrument may be used to measure the electrode current. The peak current is equal to the mean current (as measured by the meter) multiplied by the ratio of the total time to the pulse duration.

The peak reading voltage indicator of Fig. 10 may be calibrated from a known dc source if correction is made for voltage drop in the high vacuum diode. The usual practices of correcting for meter current or for voltage drop in current-measuring instruments should be followed. This type of indicator may be used also to determine peak current by measuring the peak voltage drop across a non-inductive shunt resistor of known value.

The use of this indicator for current measuring purposes may result in serious errors if the electrode characteristic of the tube under test exhibits a change of slope from positive to negative. Electrodes giving high secondary emission currents may have such characteristics, and a knowledge of the tube being tested or use of a cathode-ray oscillograph for checking purposes is desirable.

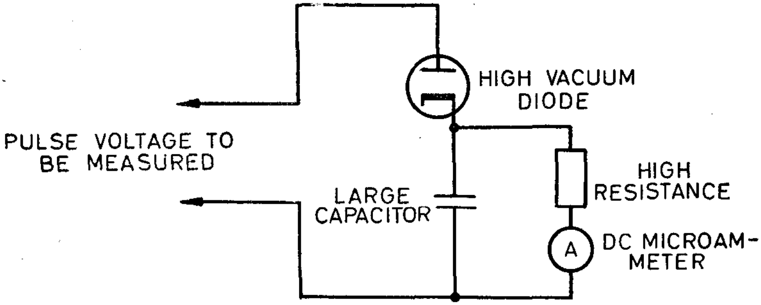


FIG. 10 PEAK READING VOLTAGE INDICATOR

4.6.4.3 *Cathode-ray oscillograph current indicator* — The indicator shown in Fig. 11 will be useful in measuring the peak value of electrode currents in taking tube characteristics by pulse method based upon circuit indicated in Fig. 8. With large tubes, connections may in most instances be made directly to the vertical deflection plates of the oscillograph. Safety and good performance require that this method be applied only to those oscillographs in which connection may be made directly to deflection plates operated at or near ground potential.

It is usually desirable to utilize a linear horizontal sweep voltage, synchronised to the pulse generator frequency, to spread out the current trace. In this manner the detection of possible errors caused by the negative slopes of electrode characteristics is simplified. In obtaining characteristics having only a positive slope, however, the peak current value may be obtained without a sweep voltage simply by measuring the height of the vertical deflection line. The dc calibrating circuit shown in Fig. 12 provides a convenient method of reading voltage drop produced in the resistor R by the electrode current. The use of a non-inductive resistor is recommended, and connecting leads should be kept as short as possible. By means of the adjustable calibrating voltage, the cathode-ray beam may be depressed until the peak deflection coincides with the zero axis. The dc meter reading is then equal to the peak voltage drop in the current measuring resistor if the reactance of the blocking capacitor is sufficiently small.

The same current indicator may be used to measure several electrode currents by switching it across various electrode current measuring resistors.

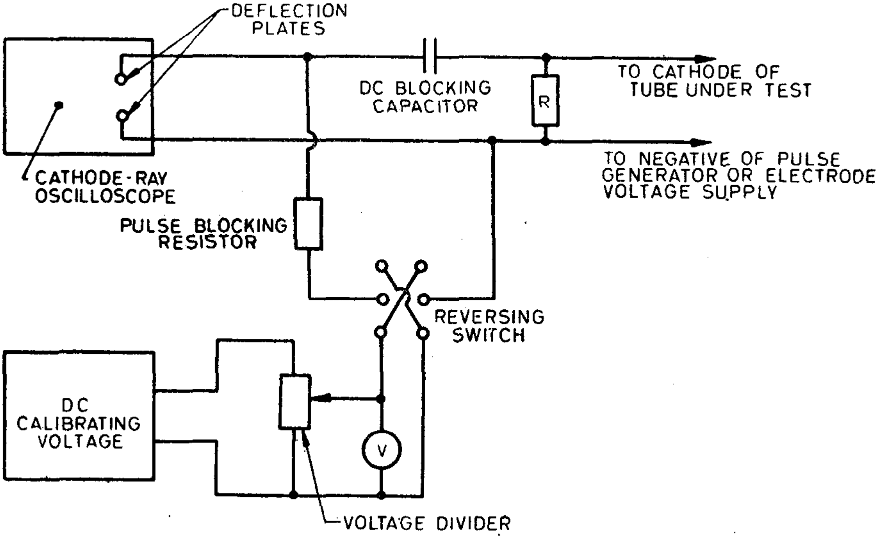


FIG 11 CIRCUIT ARRANGEMENT FOR MEASURING THE PEAK VALUE OF ELECTRODE CURRENTS

4.7 Dynamic Characteristic

4.7.1 *Direct Measurement of Load (Dynamic) Characteristic* — The load characteristics of a tube may be measured directly by the method given below.

4.7.1.1 The tube should be set up for the required operating condition and the desired load characteristic obtained by means of a cathode-ray oscillograph, the electrode voltage being applied to one pair of deflection plates and the voltage across a current measuring resistor simultaneously applied to the other pair.

4.7.1.2 At frequencies at which transit time, tube capacitance and the tube lead inductance become important, they may have considerable effect upon the load characteristic. It is, therefore, advisable to take load characteristics at the frequency at which the tube is to be used.

4.7.1.3 *Precaution* — Care shall be taken to ensure that the measuring instrument and its connecting leads do not effect the shape of the load characteristic.

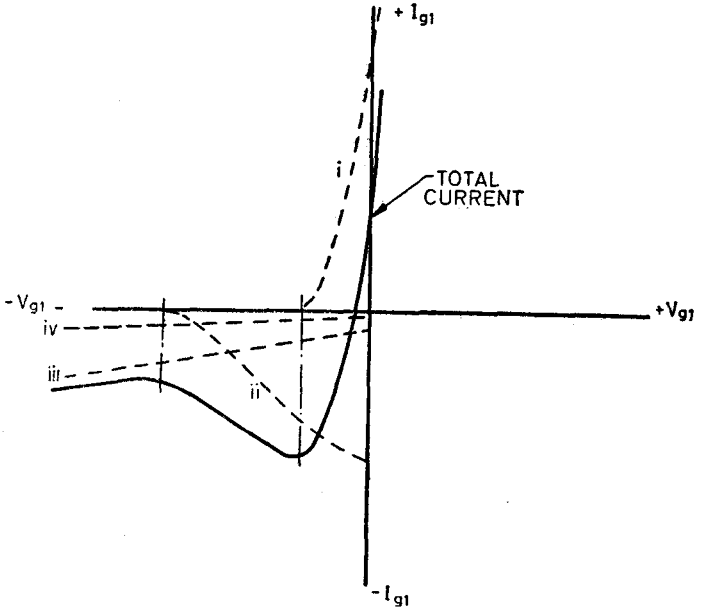


FIG. 12 TOTAL GRID CURRENT AND ITS COMPONENTS

4.8 Residual Gas and Insulation Measurements

4.8.1 Electron tubes of the same type having satisfactory static and cathode characteristics may differ from one another in the degree of vacuum and of insulation between electrodes. These properties may affect the tube life and the relative freedom from complications in tube operation. The degree of vacuum may be estimated by measuring the gas (ionization) current; and the insulation from the leakage current in the tube. In many cases, it is convenient and sufficient to measure both the currents in the circuit of the negatively biased control grid.

4.8.1.1 To separate gas current and leakage current it is necessary to vary the operating voltages. Variation of operating voltages, however, may cause the temperature of parts of the tube to vary. Because both gas current and leakage current are dependent on temperature to an extent determined by the design of the tube, it is impossible to separate a grid current into its various components with any degree of accuracy.

4.8.2 *Total Negative Grid Current* — A minute electric current can always be observed in the circuit of the negatively biased control grid of an electron tube. Usually it consists of several component currents arising from various physical phenomena. The currents are superimposed upon one another and do not all flow in the same direction. These currents (*see* Fig. 12) may result from the following causes.

a) Electrons from the cathode that reach the grid by virtue of contact potential and initial velocities (*see* curve *i*),

b) Gas (ionization) (*see* curve *ii*),

c) Leakage (*see* curve *iii*),

d) Grid current (cold), and

e) Primary electron emission from the control grid (*see* curve *iv*).

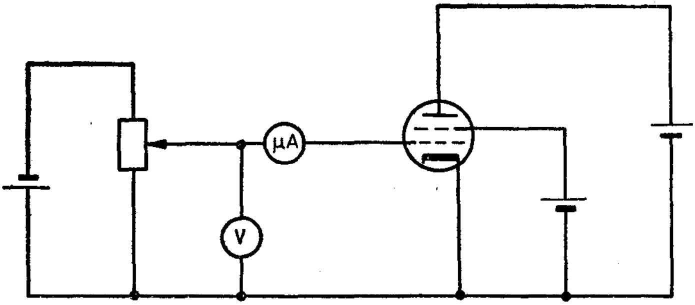


FIG. 13 CIRCUIT ARRANGEMENT FOR MEASURING THE TOTAL GRID CURRENT BY DIRECT METHOD

4.8.2.1 *Direct method* — With a negative bias on the control grid, voltages are applied to other electrodes to establish a suitable electron current. After thermal equilibrium is reached, the current in the grid circuit is measured by using a sensitive microammeter such as a spot galvanometer. The circuit arrangement is indicated in Fig. 13.

4.8.2.2 *Indirect method* — A sensitive method of measuring total control grid current, which is especially useful when the current is too small for convenient direct measurement by ordinary deflection instruments, is indicated in Fig. 14. With the switch S closed and the grid and anode voltage adjusted to the specified values, the anode current is read. Resistor R_{g1} is then inserted into the grid circuit by opening the switch, and grid bias is readjusted so that the anode current returns to its former value. The grid current I_{g1} can be computed from the change in grid voltage ΔV_{g1} necessary to main constant anode curren, since

$$I_{g1} = \frac{\Delta V_{g1}}{R_{g1}}$$

The necessary value of R_{g1} will depend upon the current to be measured. When a number of tubes of the same type are to be compared for grid current, it is often sufficient to estimate the relative grid current by noting the change in the anode current when S is opened or closed.

The sensitivity of the method can be greatly improved by balancing out the normal anode current by the arrangement shown by the dotted lines of Fig. 14, in order to permit the employment of a more sensitive anode current meter. The leakage resistance across the switch S should be large in comparison with R_{g1}.

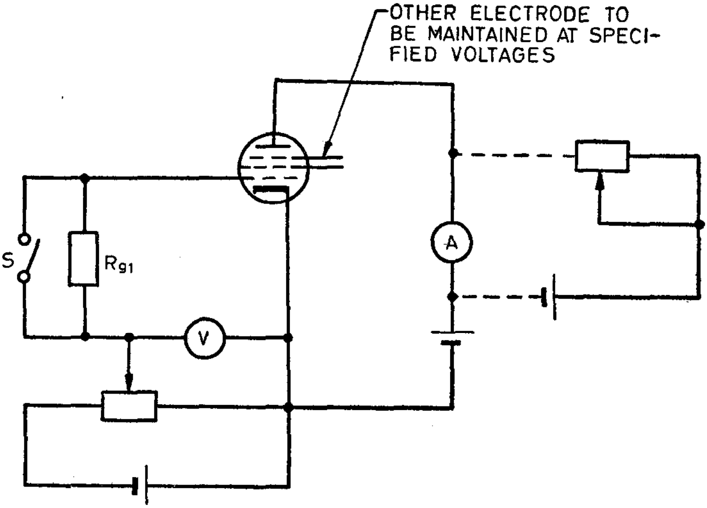


Fig. 14 Circuit Arrangement for Measuring the Total Grid Current by Indirect Method

4.8.3 *Gas (Ionization) Current* — When the electrode voltages and current are high enough, direct measurements under desired operating conditions may be made by a microammeter, as explained in **4.8.3.1**. In many cases there will not be sufficient ionization for these measurements at rated voltages. To check gas currents it is then necessary to use the indirect method as explained in **4.8.3.2**. These methods serve to compare relative ionization in tubes of a given type, but do not afford a direct comparison of gas currents under operating voltages.

4.8.3.1 *Subtraction method* — Gas current may be determined by the circuit given in Fig. 13. First, the total negative grid current is measured as described in **4.8.2**, grid bias is then increased to or slightly beyond the cut-off point and the grid current is again noted. If the primary grid emission is relatively small, gas current is approximately equal to the difference between the two readings. This is so because the gas current is included in the first readings whereas there is no gas current during the second measurement as there is no electron current to produce gas ions. The second reading includes leakage current and primary grid emission current. Leakage current may be assumed to be proportional to the grid voltage.

NOTE — If the primary grid emission is not small, the results obtained by this method may be misleading. The primary grid emission current will increase with grid voltage and may cause the difference between the two readings to be zero or even negative. Other method is then required to evaluate the results.

4.8.3.2 *Ionization-gauge method* — In many types of electron tubes, the degree of vacuum can be estimated without measuring the negative grid current. The method is based upon a circuit examplified by Fig. 15 in which a positive voltage greater than the ionization potential is applied to the control grid and a negative voltage is applied to one or more other electrodes. Positive ions formed by the collision of electrons with gas molecules are collected by the negative electrodes. The resulting positive-ion current gives an indication of the gas density, and, therefore, gives a means for comparison of the degree of vacuum of individual tubes of the same design. Since the nature of the gas influences the measurements, it shall be considered when measurements are made with different gases.

Precautions — Although the cathode temperature in this test shall be adjusted to give a sufficiently high grid current of convenient readings, the grid current should not be too high because bombardment of the grid may cause gas evolution. The degree of vacuum in tubes of the same design may be compared if the grid voltage is kept constant and if constant grid current is maintained by adjusting the cathode temperature. Retarding-field oscillations that may occur during measurements in this circuit shall be avoided by proper choice of voltage.

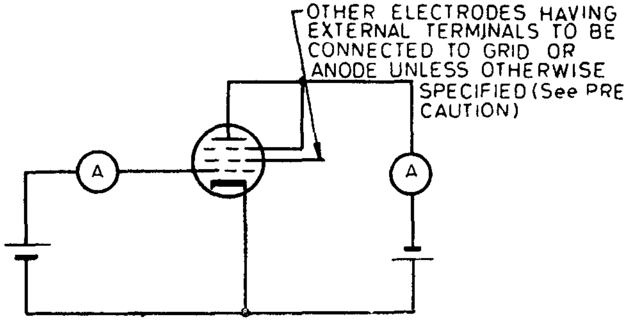

OTHER ELECTRODES HAVING EXTERNAL TERMINALS TO BE CONNECTED TO GRID OR ANODE UNLESS OTHERWISE SPECIFIED (See PRECAUTION)
A
A

Fig. 15 Circuit Arrangement for Measuring Gas Current, Ionization-Gauge Method

4.8.4 *Grid Leakage* — This test applies to tubes where grid leakage is high compared to grid emission. At the conclusion of the test specified in **4.8.2** above, the filament or heater voltage shall be cut off and the grid current measured when the parts have cooled. This current shall be considered to be due to leakage and shall not exceed the limit specified.

4.8.5 *Grid Current* (*Cold*) — The filament switch shall be opened until the elements have cooled below visible colour. The filament switch shall then be closed and the value of the grid current at the first pause in its rising value shall not exceed the value specified.

4.8.6 *Primary Grid Emission* — By means of suitable rectifiers and a 50 Hz ac source, the grid shall be heated during the positive half cycles; and the primary emission measured during the negative half cycles. The voltage shall be adjusted for the input power or average grid current specified. The primary emission current shall not be greater than the limit specified.

4.8.7 *Insulation of Electrodes*

4.8.7.1 Tests shall be carried with each control grid to all other elements tied and each anode to all other elements tied. In the test set, the centre tap or one side of the filament transformer shall be tied to the positive terminal. When testing multi-section tubes, all elements of sections not under test shall be connected to the positive terminal. The value of the insulation resistance, measured with the applied potential specified in **4.8.7.2**, **4.8.7.3** and **4.8.7.4** below as applicable, shall be not less than 100 megohms for reliable tubes and not less than 10 megohms for all other receiving tubes. This test shall be performed with the filament energised immediately after the other specified electrical tests are concluded or immediately following a minimum pre-heating time of 5 minutes.

4.8.7.2 *Receiving tubes with a maximum anode potential rating greater than 330 V dc* — Receiving tubes with maximum anode potential rating greater than 330 V dc, or rectifiers whose maximum rms test voltage per anode exceeds 300 V dc, shall be tested with a negative potential of at least 500 V dc when measuring insulation resistance from anode to all other elements tied. The applied potential shall be not less than — 300 V dc when measuring insulation resistance from each control grid to all other elements tied.

4.8.7.3 *Receiving tubes with maximum anode potential rating of 330 V dc or less* — Receiving tubes with a maximum anode potential rating equal to or less than 330 V dc, except those intended for dry battery operation, or rectifiers whose maximum rms test voltage per anode is less than 300 V ac, shall be tested with a negative potential of at least 300 V dc when measuring insulation resistance from anode to all other elements tied; however, the applied potential shall be a negative voltage of at least 100 V dc when measuring insulation resistance from each control grid to all other elements tied.

4.8.7.4 For tubes other than receiving, the value of insulation resistance and the applicable voltages shall be specified in the detail specification.

Precautions — Since these measurements may include emission currents from various electrodes, care should be taken that conditions are such as to preclude such emission. These conditions may be approached by heating the tube under normal operating conditions, turning off the filament or heater, and making measurements as soon thereafter as the electrodes have cooled to the point where electron emission currents will be negligible.

4.8.8 *Heater-Cathode Leakage Current*—Leakage current between the heater and the cathode of a tube should be measured with the rated heater voltage applied, sufficient time being allowed for the heater and the cathode to attain normal temperature. The heater voltage may be either alternating or direct, as convenient. A voltage is applied in series with a microammeter between the heater and the cathode and the current is measured (due allowance being made for any voltage drop across the protective resistor). Measurements of heater-cathode leakage current may be made with alternating voltage or with direct voltage of either polarity. Because the current obtained will rarely be the same under the three conditions, the conditions of test shall be specified. Similarly, where the heater voltage is appreciable compared with the measuring voltage, the point of connection to the heater circuit shall be specified. The voltage on elements other than heater and cathode may influence the results because of stray electron currents, and should be specified in the test conditions.

4.9 Inverse Electrode Currents

4.9.1 Thermal electron emission currents from elements other than the cathode may be of sufficient magnitude to affect the performance of electron tubes. Measuring methods are described below for thermal electron emission from the control-grid, screen-grid and the anode of amplifier tubes and the anode of diode rectifiers.

4.9.1.1 Secondary electron emission from control-grids may also affect performance and control tests may be desirable.

4.9.2 *Thermal Grid Emission* — During tube operation, the control grid is subjected to heating by radiation and by electron bombardment when the grid potential becomes positive. As a result, the grid temperature may reach the level at which grid begins to emit electrons. Consequently, an electron current from the grid to the other electrodes may flow whenever the grid is negative with respect to these electrodes. The amount of such thermal electron emission, and the conditions under which its effect becomes appreciable may be determined by one of the following two methods.

4.9.2.1 *Subtraction method* — The total negative grid current measured beyond the cut-off point, as described in **4.8.3.1**, consists of the leakage current and the thermal grid emission current. Since grid leakage can be measured independently, it can be subtracted from the total measured current to give the value of thermal electron current. If the leakage current is negligible, the original measurement gives the grid emission current directly.

NOTE — The grid emission and leakage currents are both related to temperature. Therefore, the total grid current shall be measured as quickly as possible after the cathode current is cut off. The value of leakage current measured shall be corrected to the voltage at which the total current was measured.

4.9.2.2 *Dynamic method* — Measurement of thermal grid emission as a function of grid dissipation power may be accomplished by the use of the circuit shown in Fig. 16. In this arrangement the grid of the tube under test is heated by 50-cycle power from transformer T_1 on every alternate half-cycle through rectifier V_1 and ammeter A_1. On the reserve half-cycle of transformer T_1, a sensitive ammeter A_2 in series with rectifier V_2 indicates the thermal grid emission current (and leakage current if present). The battery B and potentiometer R are included to provide a means of bucking out spurious currents around the $V_1 — V_2$ loop caused by contact potential and initial velocities. Voltmeter V in series with rectifier V_3 serves to indicate the voltage on the grid on the heating half-cycle. With proper regard to the form factors of the various voltages and currents, the thermal grid emission current versus grid dissipation may be calculated. If a wattmeter is used in place of ammeter A_1 and voltmeter V, the grid dissipation can be read directly.

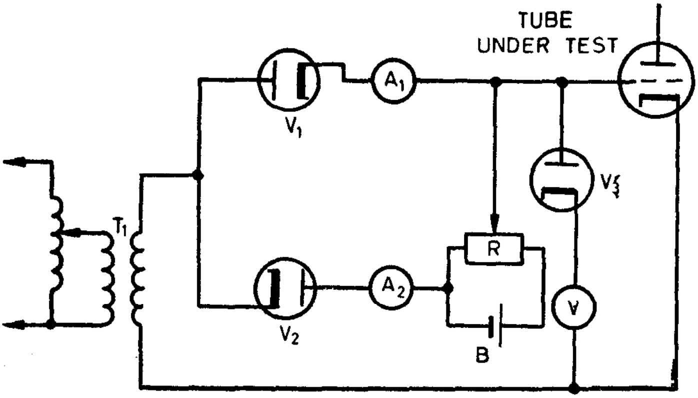


FIG. 16 CIRCUIT ARRANGEMENT FOR MEASURING PRIMARY GRID EMISSION, DYNAMIC METHOD

4.9.3 *Secondary Grid Emission* — Secondary electron emission from the grid surface as a result of electron bombardment is an ever-present phenomenon in electron tubes when positive potentials are applied to the grid statically or dynamically. Secondary electron emission current flows from the grid to other more positive electrodes as long as electron current flows to the grid. In external grid circuit the bombarding current and the secondary emission current flow in opposite directions, and only their difference may be observed on a meter.

4.9.3.1 Pronounced secondary grid emission in an electron tube amplifier or oscillator may help tube operation by increasing the output and efficiency or by reducing the grid-excitation power. It may, however, interfere with tube operation by preventing the realisation of linear amplification or by causing parasitic oscillations. Secondary grid emission may exert a detrimental effect when it is of such magnitude as to produce a negative grid resistance. Negative grid resistance is evidenced by a negative slope of the curve of grid current versus grid voltage, or even by reversal of grid current. In Fig. 17 the effect of secondary grid emission on the grid charrcteristic is shown. Curve I shows no appreciable secondary emission and curve II appreciable secondary emission. Curve III, however, shows pronounced secondary emission in which region ‘ a ’ of the curve is a negative resistance region.

4.9.3.2 The amount of secondary emission from the grid of an electron tube cannot be measured directly. Tube of the same type, however, may be compared as to the relative amount of secondary grid emission present by projecting a grid characteristic upon the screen of a cathode-ray tube or by checking by static means of a point on the grid characteristic for chosen values of electrode voltages. If a static test is used, electrode voltages shall be chosen that do not result in excessive electrode dissipation.

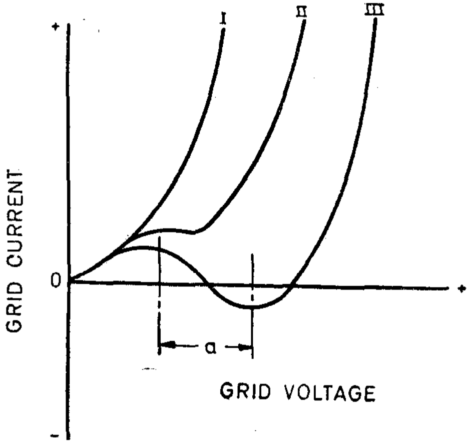


Fig. 17 Typical Grid Characteristics Showing Effects of Secondary Emission

4.9.4 *Back Emission in Rectifier Diodes* — Back emission in a rectifier is the inverse thermal electron current between anode and cathode. If the dissipation during the conducting part of the cycle is sufficient to cause heating of the anode to a temperature high enough to enable it to emit electrons, the released electrons will bombard the cathode during the time in which the cathode is positive with respect to the anode. A basic circuit suitable for the measurement of back emission is shown in Fig. 18. The tube under test is operated as a half-wave rectifier and loaded by R_1 and C. V_1 is a diode of very low impedance compared with that of tube under test and may conveniently be a gas-filled tube. The impedance of the rectifier V_2 may be higher than that of V_1. R_2 is a limit-resistor to protect the meter A_2 in the event of flash-over in the tube under test. The battery B and potentiometer R_3 are included to cancel out circulating currents in the $V_1 - V_2$ loop due to contact potential and initial velocities.

4.9.4.1 During the conducting part of the cycle, the tube under test and V_1 conduct and, since V has a very low impedance compared with the tube under test, the time constants of the circuits will not be disturbed. During the non-conducting part of the cycle, any reverse current in the tube under test is fed through V_2 and the meter A_2. This current is made up of back-emission and ohmic-leakage currents through the tube under test. If a curve of back emission current against output current from the tube under test is plotted, it will take the form shown in Fig. 19.

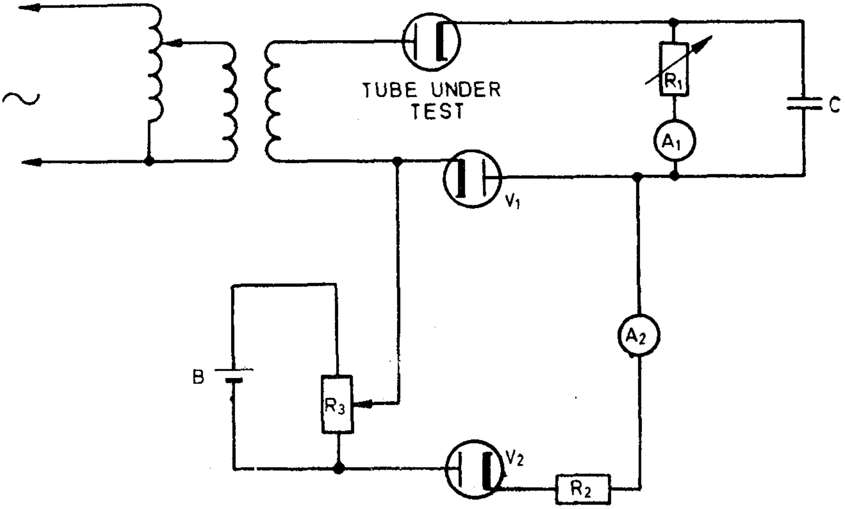


Fig. 18 Circuit Arrangement for Measuring Back Emission

4.9.4.2 At low values of output current the reverse current consists entirely of the ohmic-leakage current and tends to decrease in value with increase in output current. The decrease occurs because the peak-inverse voltage across the tube under test is decreasing. As the temperature of the anode rises, the thermal electron emission from it may increase rapidly, as shown in Fig. 19 by CD.

4.9.5 *Operation of Rectifiers*

4.9.5.1 Each tube shall operate satisfactorily and without rejectable arc-backs in a rectifier circuit under the conditions specified. The criteria for rejetable arc-back and their detection shall be as specified in **4.9.5.2** to **4.9.5.4** inclusive, as applicable, or as specified. When the test conditions specify circuit constants, the dc current in the load resistor shall be within the limits specified. The duration of test shall be sufficient to obtain indication of satisfactory operation. For mercury-vapour rectifiers, the cathode shall be allowed to be heated for a period of time sufficient to distribute the mercury properly in the bulb. Inductive loading shall not be used. Unless otherwise specified, rejectable arc-backs do not apply to life tests.

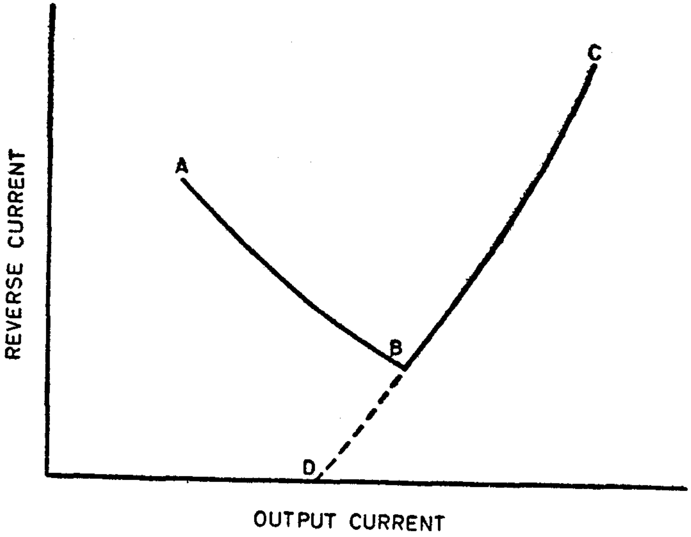


FIG 19 TYPICAL CURVE OF REVERSE CURRENT VS OUTPUT CURRENT IN RECTIFIER

4.9.5.2 *Receiving-type rectifiers* — In the operation of receiving-type rectifiers, a rejectable arc-back is one which has a peak reverse current at least 3·5 times the rated peak steady-state anode current per anode and which occurs after a delay of at least 5 input frequency cycles from the time of application of anode voltage. (This delay distinguishes arcs attributable to the tube from those which result from transient instability of the test equipment). The arc-back detector shall have a maximum charging time constant of 0·5 millisecond and shall be capable of detecting a single rectangular peak of 0·5 millisecond duration with an amplitude of 3·5 times the rated peak steady-state anode current per anode. The minimum test time shall be the time required for the tube under test to reach the minimum operation current, I_0, specified in the detail specification. The tube may be preheated at rated heater or filament voltage at the option of the manufacturer. This is not a destructive test.

4.9.5.3 *Gas rectifiers* — In the operation of gas rectifiers, a rejectable arc-back is one which has a current in the reverse direction whose peak value is not less than five times the peak forward anode current obtained during this test. In the test circuit, the source impedance shall be such that the peak value of the steady-state current in the shorting circuit, when all tubes are short circuited, shall not be less than 7·5 times the peak forward anode current obtained during this test. The arc-back detector shall be capable of detecting a rejectable arc current whose duration is equal to or greater than 1/4 cycle of the frequency of applied voltage. Unless otherwise specified, the frequency of operation shall be 50 Hz. Samples shall be operated for 1 hour.

4.9.5.4 *Power vacuum rectifiers* — In the operation of power rectifiers, a rejectable arc-back is one which has a peak reverse current at least 3·5 times the rated peak steady-state anode current. In the test circuit, the source impedance shall be such that the peak value of the steady-state current in the shorting circuit, when all tubes are short circuited, shall be at least four times the peak forward anode current obtained during this test. The arc-back detector shall be capable of detecing a rejectable arc current whose duration is equal to or greater than 1/4 cycle of the frequency of applied voltage. The frequency of the applied voltage shall be 50 Hz. Samples shall be operated for 1 hour.

4.9.6 *Primary Screen-Grid Emission* — Measurement of thermal screen-grid emission as a function of the power dissipation may be accomplished by use of the circuit shown in Fig. 20. By means of suitable rectifiers and a 50 Hz source, the screen is heated during the positive half-cycles and the primary emission is measured during the negative half-cycles. Appropriate direct anode voltage and control grid bias are applied to the tube, and the screen dissipation is set to the desired level by adjusting the alternating input voltage of the transformer and reading current on meter A_1 and voltage on voltmeter V. V_1 is a diode of very low impedance compared to the impedance of the screen circuit. The current read on meter A_2 is the primary screen emission (usually in the order of micro-amperes) under the conditions of test.

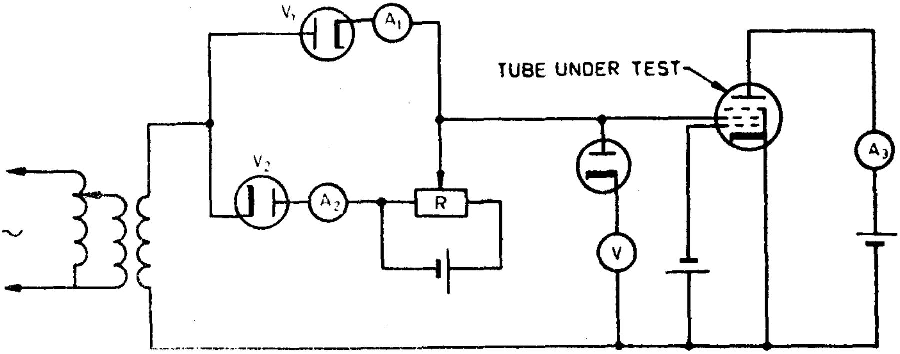


FIG. 20 CIRCUIT ARRANGEMENT FOR MEASURING PRIMARY EMISSION FROM SCREEN GRID OF A PENTODE

4.9.6.1 A wattmeter instead of voltmeter V and ammeter A_1 will serve to establish screen dissipation in this test without tedious calculation.

4.9.6.2 In some cases a simplified version of this circuit will give useful information, without the direct voltage supply and with the anode and control grid tied to cathode.

4.9.7 *Primary Anode Emission* — Measurement of the thermal electron emission from the anode as a function of dissipation may be accomplished by the circuit of Fig. 21, which is similar in principle to the circuit discussed in **4.9.6** for the screen emission measurement. The desired anode dissipation is obtained by applying alternating voltage to the anode and reading current on ammeter A_1 and voltage on voltmeter V. Appropriate values of screen and control grid bias are applied. The primary anode emission is read on meter A_2.

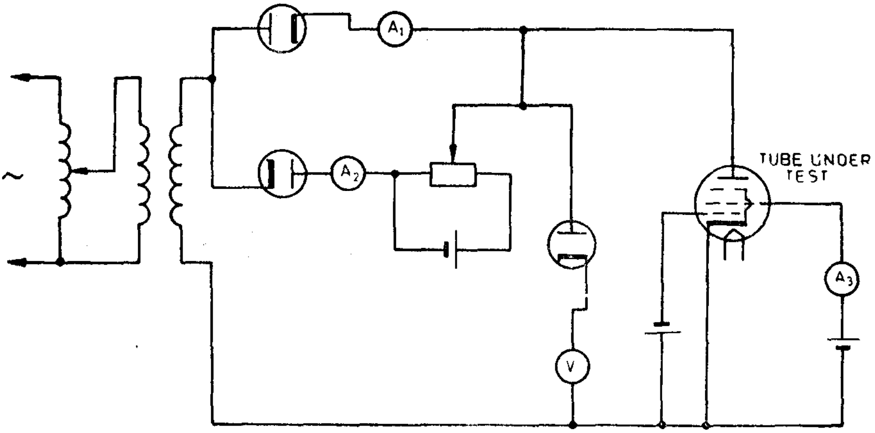


FIG. 21 CIRCUIT ARRANGEMENT FOR MEASURING PRIMARY EMISSION FROM ANODE OF A PENTODE

4.10 Inter-Electrode Capacitances

4.10.1 It is recommended that direct capacitances be measured, rather than total capacitances, each of which is the sum of two or more direct capacitances. In measurements of direct capacitances between two electrodes of multi-electrode tubes, it is customary to connect all other electrode to ground unless another connection is desired which more nearly simulates the circuit operating conditions. Published capacitance values usually specify connections for the other electrodes. In general it is customary to connect the heaters and the screen-grid to the cathode and to connect other sections or units to ground. Information as to the electrode connections for specific published capacitance values should be obtained from the published data sheets. The three direct capacitances of a triode are anode-grid capacitance C_{ag}, grid-cathode capacitance C_{gk} and anode-cathode capacitance C_{ak}. When a tube is active, its direct inter-electrode capacitances differ from the values obtained with a cold tube. The difference may be sufficient to be of importance in certain applications. Inter-electrode capacitances, unless otherwise specified are measured with the cathode cold and with no direct voltages present.

4.10.2 *Radio-Frequency Bridge Method* — A bridge circuit for the measurement of direct inter-electrode capacitances of a tube is shown in Fig. 22. A stable oscillator, such as a crystal controlled oscillator, supplies RF through a closely coupled balanced transformer. Balance is indicated by a null-indicating tube voltmeter which is made up of a tuned amplifier, diode rectifier and direct current meter indicator. It is customary to use a stable communication receiver as a detector. For convenience, the capacitors are ganged differentially so that increase of one capacitance is accompanied by an equal decrease of the other.

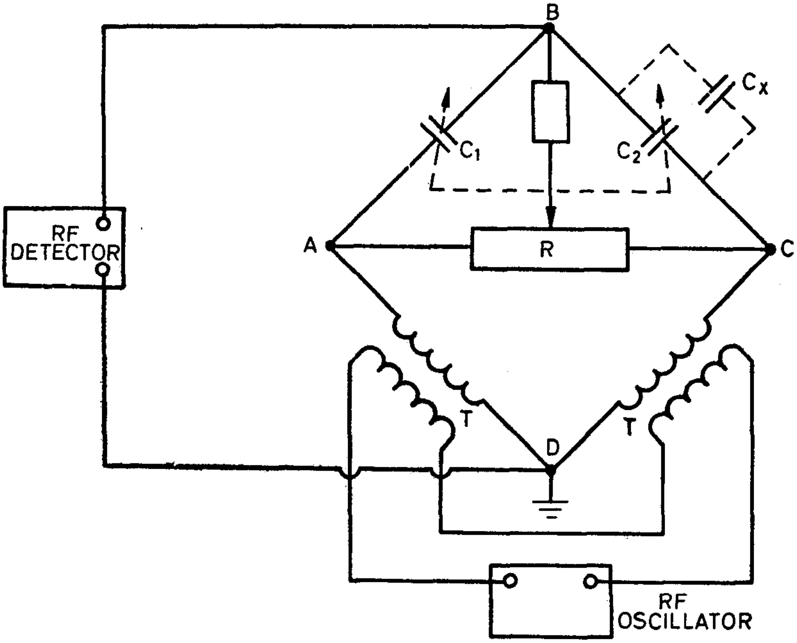
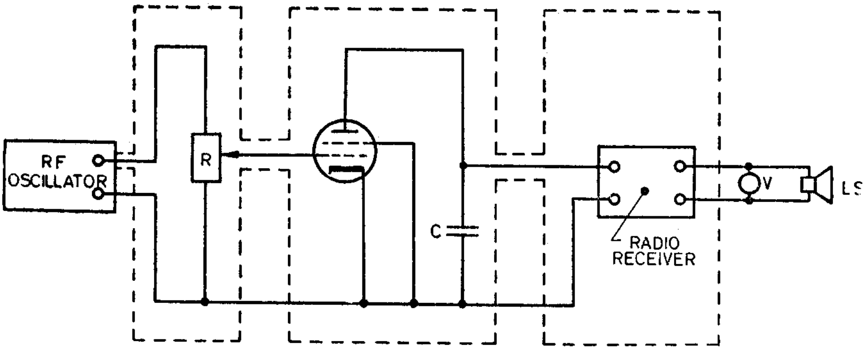


FIG. 22 CIRCUIT ARRANGEMENT FOR *RF* BRIDGE FOR MEASURING INTER-ELECTRODE CAPACITANCES

4.10.2.1 Balance may then be effected by varying the two capacitance branches until they are equal (when $C_x = C_1 - C_2$). Then at balance $C_x = | 2 \triangle C_1 | = | 2 \triangle C_2 |$. When an adapter is used, the tube capacitance is the difference in capacitance readings with the tube in and out of the adapter. An advantage of the bridge over the other methods is that the conductive components of the tube admittances due to insulation losses, getter deposits or other leakages may be measured and balanced out independently of the capacitance reading. The effect of capacitance to ground is negligible as point *B* is at centre location in the bridge, where capacitance does not influence balance; and the capacitance from *C* to ground is across a closely coupled low-impedance winding that does not affect the capacitance balance or the voltage supplied to the bridge.

4.10.3 *Substitution Method*

4.10.3.1 A substitution method of high sensitivity for small capacitances such as the anode-grid capacitance of screen-grid tubes is shown in Fig. 23. This method employs a calibrated variable voltage source and a fixed standard capacitor. A standard signal generator is convenient for this purpose. The current through the anode-grid capacitance of the tube produces a voltage across the receiver input, which is shunted by a large capacitance *C*. In the arrangement shown in Fig. 23 the RF oscillator is modulated, and an ac voltmeter connected across the terminals of the loudspeaker is used as an indicator.



R = Attenuator
C = Large shunt capacitor
V = ac Voltmeter
LS =Loud spkeer

FIG. 23 CIRCUIT ARRANGEMENT FOR MEASURING INTER-ELECTRODE CAPACITANCE BE SUBSTITUTION METHOD

A standard fixed capacitor C_s of the order of 0·5 pF, suitably shielded, is first used in place of the tube shown in Fig. 24 and the attenuator is set so that the impressed RF voltage is V_s with a standard AF output.

The tube to be measured is next substituted for the standard capacitor and the attenuator readjusted until an impressed RF voltage V_x produces the same deflection at V. The unknown anode-grid capacitance is given by:

$$C_{ag1} = \frac{C_S V_S}{V_x}$$

The standard capacitor may be enclosed within a vacuum tube of standard dimensions. Two circular disks 2 cm in diameter and spaced 8 mm apart, will provide a standard capacitor of the proper order of magnitude. It may be calibrated by measurements on a differential capacitance bridge.

4.10.3.2 *Precautions* — The leads from the attenuator to the tube shield and from the latter to the voltage measuring unit should be completely shielded, and the tube itself should be enclosed in a rather closely fitting cylindrical shield. For a double-ended tube, the test set should be provided with a small contactor to the grid (or anode) cap, the lead to this connector entering at the top of the shield. The lead from the anode or grid leaves at a point near the bottom of the shield. For a single-ended tube shielding adequate for the elimination of capacitance components between the active tube and socket terminals should be provided. The adequacy of the shielding may be checked by readings made with the tube removed from the socket, unless the tube base itself provides the shield.

The shunt capacitance C should be large compared to the anode-grid capacitance of the tube under test; ordinarily a value of 500 pF is satisfactory.

4.11 Tube Coefficients

4.11.1 This section is devoted to methods of measuring the low frequency coefficients of electron tubes. The more commonly used coefficients are anode resistance, grid-anode mutual conductance, amplification factor and conversion conductance. The methods outlined apply not only to these coefficients, but also to the less commonly used coefficients referred to any one or to any pair of electrodes such as grid resistance, conductance for rectification, grid-screen μ factor, etc.

4.11.1.1 In general most tube coefficients may be evaluated from the characteristic curves or may be measured directly by a balance or null method of measurement employing an audio-frequency generator as the source of power and a null indicator (usually a telephone receiver which is preceded by an amplifier for more precise results). The results obtained by balance methods are usually more reliable than the results obtained from the characteristics curves, particularly in the measurement of coefficients of oxide coated cathode tubes.

4.11.2 *Anode Resistance*

4.11.2.1 *Bridge method* — Anode resistance may be determined by using the bridge illustrated in Fig. 24. At balance, the anode resistance r_a is given by the relation:

$$r_a = \frac{R_1 R_3}{R_2}$$

In bridge measurements the quadrature current is usually best balanced out by a small capacitor in an arm of the bridge adjacent to the arm containing the unknown. Care should be taken in choosing the bridge arm resistances to ensure that the current flowing to the electrode does not vary appreciably while the bridge is being balanced to a null.

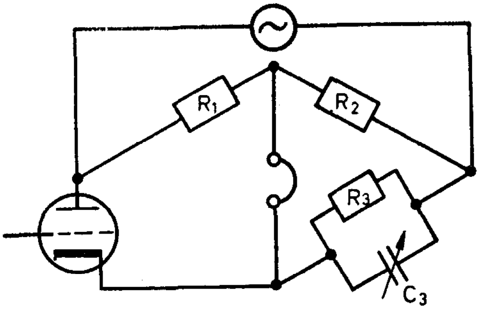


FIG. 24 BASIC RESISTANCE-BALANCE CIRCUIT FOR MEASURING ELECTRODE RESISTANCE

4.11.2.2 *Substitution method* — This method lends itself to rapid determination of the anode resistance r_a of tubes such as the screen-grid type where the value of anode resistance is above 0·5 megohm. The circuit arrangement is shown in Fig. 25.

The tube is operated at normal voltages. Switch S is open. Alternating voltage is applied as indicated and adjusted until a convenient deflection is obtained on the electronic voltmeter. The tube is then removed from the circuit and a resistor R_1 substituted for the internal resistance of the tube by closing switch S. R_1 is then adjusted to give the same deflection on the electronic voltmeter with the alternating voltage held constant at its original value. The value of R_1 is then the value of the anode resistance of the tube. R_2 should be made negligibly small in comparison with the anode resistance of the tube.

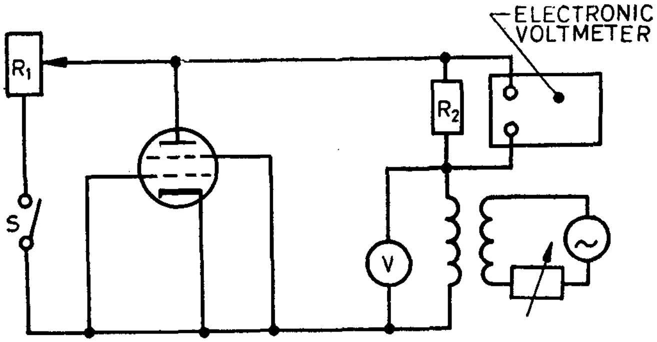


FIG. 25 BASIC CIRCUIT FOR MEASURING THE ANODE RESISTANCE OF SCREEN-GRID TUBES BY THE SUBSTITUTION METHOD

The arrangement can be made into a direct reading device in the following three ways:

a) By maintaining the alternating voltage constant and calibrating the electronic voltmeter in terms of anode resistance of the tube. R_1 may be used in the manner described above for making calibration.

b) By maintaining the deflection of the electronic voltmeter constant and calibrating the alternating current voltmeter in terms of the tube anode resistance, R_1 being used for calibration purposes. This method gives a straight line calibration between the alternating voltage and the tube anode resistance and is more conveniently used than (a).

c) By maintaining the alternating voltage constant and varying R_0 to give constant deflection on the electronic voltmeter. The r_a will be proportional to R_2.

4.11.3 *Mutual Conductance*

4.11.3.1 *Method 1* — A balance method for measuring mutual conductance g_m is shown in Fig. 26. At null condition, mutual conductance is given by the expression:

$$g_m = \frac{R_2}{R_1 R_3}\left(1 + \frac{R_3}{r_a}\right)\left(1 + \frac{R_1}{R_g}\right)$$

If R_3 and R_1 are negligibly small compared with the resistance of anode (r_a) and grid (R_g), the balance equation reduces to:

$$g_m \doteq \frac{R_2}{R_1 \times R_3}$$

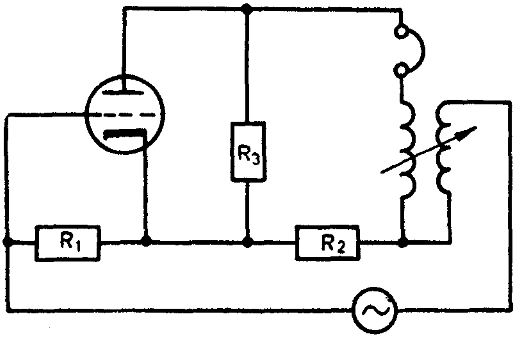


FIG. 26 BASIC RESISTANCE-BALANCE CIRCUIT FOR MEASURING MUTAL CONDUCTANCE

4.11.3.2 *Method 2* — A second balance method, which is useful for measuring the mutual conductance of power tubes or in general when r_a is small, is shown in Fig. 27. The null is obtained by adjusting R_s and at balance the mutual conductance is given by:

$$g_m = \frac{1}{R_s}$$

The value of the resistance in the grid circuit does not affect the measurement.

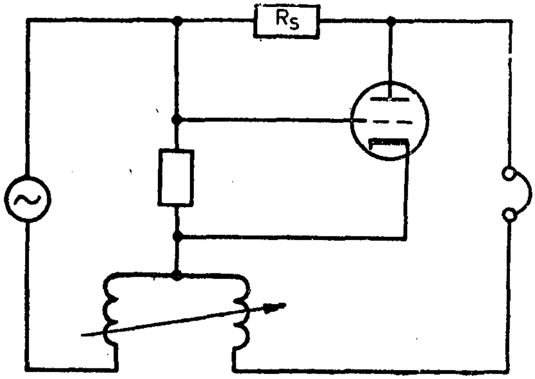


FIG. 27 BASIC RESISTANCE CIRCUIT FOR MEASURING THE MUTUAL CONDUCTANCE OF POWER TUBES

4.11.4 *Amplification Factor* — The circuit illustrated in Fig. 28 may be used for the measurement of amplification factor. In determining the amplification factor, the null detector shall ordinarily be placed in the anode circuit since the defining equation states that the alternating component of the anode current is zero. If the tube is a triode and if there is no grid current flowing, the null detector may be placed in the cathode circuit. The impedance of C_2 shall be negligible in comparison with resistance R_2 at the test frequency. At balance, the amplification factor is given by:

$$\mu = \frac{R_2}{R_1}$$

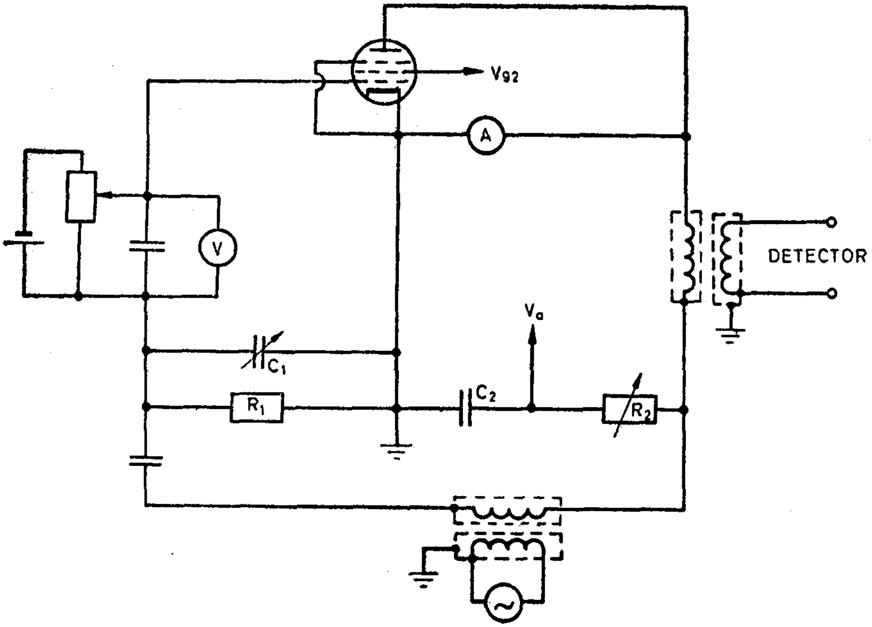


FIG. 28 CIRCUIT ARRANGEMENT FOR MEASURING THE AMPLIFICATION FACTOR

4.11.5 *General Precautions for Balance Methods* — The magnitude of the impressed alternating voltage should always be sufficiently small so that the results of the measurement are unaffected by a reduction of the impressed voltage. All electrodes not directly involved in the measurement shall be maintained constant at specified voltages.

4.11.5.1 Balance methods employing an alternating voltage generator require that consideration be given to the effects of stray capacitances and couplings, which may render balance difficult or impossible. The grounding and shielding of apparatus should be given special attention.

4.11.5.2 Batteries and, in particular, dc supplies operated from the power line may introduce excessive capacitance across the network elements unless properly located with respect to ground. In the example of Fig. 28, the anode and screen supplies are at ground potential and the capacitance of the grid supply may be neglected because of the low resistance of R_1. Capacitors of sufficiently low impedance to by-pass the AF currents shall usually be shunted across the power supplies. Voltage regulated power supplies are excellent low-impedance devices for this purpose.

4.11.5.3 Audio frequency generators and amplifiers that are operated from the power line will have appreciable capacitance to ground the effect of which may usually be minimized by the use of shielded transformers.

4.11.5.4 When direct current flows through the generator or through the detector, low resistance transformers or chokes shall be used to minimize the direct voltage drop. Spurious couplings between the chokes or transformers shall then be prevented by proper shielding, orientation and spacing of the component parts.

4.11.5.5 In some circuits the direct voltage at an electrode may vary as balance adjustments are made. When this cannot be avoided by means of a blocking capacitor or by circuit rearrangement, the direct voltage is best measured at the electrode (as in Fig. 28 by A) with a meter of sufficiently high resistance to preclude errors due to its shunting effect. Circuit resistors shall be able to carry the electrode currents with negligible effect on their resistance value.

4.11.5.6 In the measurements of the coefficients of high mutual conductance tubes, oscillations may occur. Oscillations of the tube under test may be evident in the lack of a sharp null point or may not be evident except in erroneous readings. Checks by other methods should therefore be made to establish freedom from oscillation in setting up a new bridge or in measuring high mutual conductance values. Oscillations may be checked by the presence of grid current or by the change of anode current when the grid or anode terminal is grounded for the spurious frequency. Oscillation may be prevented by exercising care in choosing the length and location of the leads to the tube sockets, by the judicious use of by pass capacitors, or by the insertions of a resistor in series with the appropriate electrode.

4.11.5.7 Circuit and inter-electrode capacitances introduce quadrature currents that may have to be balanced out to attain an exact null. Various methods of quadrature balance are available. The mutual inductance method illustrated in Fig. 27 couples, in proper phase, voltage from the generator to the detector (or, on occasion, to the grid, circuit if there is no grid current). Because of the resistance, self-inductance and mutual inductance introduced in series with the detector, the balance conditions are modified and a slight error may exist. In the capacitance method a small variable capacitor is used, as for example at C_1 in Fig. 28. Both of these methods require readjustment of the circuit for every change in the main balance network. This difficulty may be avoided by using an auxiliary capacitance bridge to balance out the quadrature component before the tube heater or filament is turned on.

4.11.6 *Conversion Conductance*

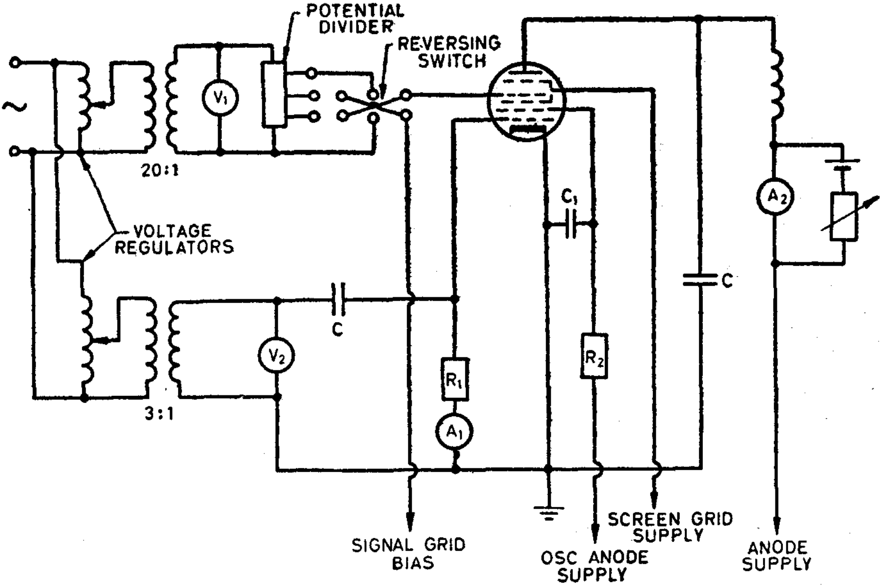
4.11.6.1 The definition of conversion conductance shows that if $f_1 = f_2$ where f_1 is the frequency component of current and f_2 is the frequency component of voltage, the difference frequency will be zero, corresponding to direct current. If the two signals are in phase, the anode current will be higher than with the two signals 180° out of phase. The difference in direct anode current, caused by a reversal of the phase relation of the two signals, divided by twice the peak value of the alternating voltage on the signal grid is the conversion conductance. It is assumed that the voltage on the oscillator grid is adjusted to such a value that the current drawn by the grid corresponds to its rated value. Measurement of conversion conductance is not applicable to transmitting tubes.

4.11.6.2 In practice, measurements may be made on multi-grid converter and mixer tubes in a circuit similar to that shown in Fig. 29. With grid resistor R_1 and grid current as rated, a signal voltage V_g is applied to the signal grid 180° out of phase with the voltage applied to the oscillator grid. The bucking circuit is adjusted to give zero reading of the anode current meter, after which the phase of the signal voltage applied to one of the grids is reversed and the reading of the anode current meter ΔI_a noted. Conversion condutcance g_c is then given by:

$$g_c = \frac{\Delta I_a}{2 \cdot \sqrt{2} \cdot V_g}$$

4.11.6.3 For precision measurements, the signal voltage applied to the signal grid should be held to as low a value as possible, and in no case should cause current to flow in the signal grid circuit. For most converter tubes, it is convenient to make V_g equal to 0·354 volt rms. The conversion conductance in micromhos is then numerically equal to ΔI_a in microampheres.

4.11.6.4 In the circuit of Fig. 29 it should be noted that the transformers and regulators shall have sufficiently low leakage reactance and resistance to maintain exact phase relation between the signal and grid driving voltages. The regulators may be variable auto transformers or the equivalent. The resistance of the bucking circuit shall be high compared to the resistance of the anode current meter (a ratio of 10 : 1 will produce an error of about 10 percent and 100 : 1 will result in an error of about 1 percent).



C = 5/μF
C_1 = 2/μF
R_1 = Grid leak
R_2 = Anode-Grid limiting resistor
V_1 = ac Voltmeter 0-5 volts
V_2 = ac Voltmeter 0-30 volts
A_1 = dc Ammeter 0-1A
A_2 = dc Multirange Ammeter 0-0-1-1-10A

FIG. 29 CIRCUIT ARRANGEMENT FOR MEASURING CONVERSION CONDUCTANCE

4.11.6.5 The following procedure shall be followed in making conversion conductance measurements when a screen-voltage dropping resistor is included in the test circuit to simulate the normal circuit with the resistor by-passed:

a) With the screen resistor in the circuit, adequately by-passed for 50 Hz current, and with zero signal on the signal grid and normal oscillator grid current, read the screen current; and

b) Remove the screen resistor and apply a voltage to the screen equal to the supply voltage minus the voltage drop computed from the screen current determined above.

Then conversion conductance is read in the usual manner.

4.11.6.6 When a tube is to be operated with grid-resistor bias, conversion conductance shall be measured with a separate bias, adjusted to give the same anode current as would be obtained with the grid-resistor bias.

4.11.6.7 When a tube is to be operated with a cathode bias resistor included in the test circuit to simulate the normal circuit with the resistor by-passed, the following procedure should be used:

a) With the cathode resistor in the circuit adequately by-passed for 50 Hz current and with the correct oscillator-grid current and specified grid resistor, the individual currents are read; and

b) The cathode resistor is removed or short-circuited and bias is applied to the control grid. The control grid and screen voltages are adjusted to give the same electrode currents as before.

The conversion conductance is then read in the usual manner for each value, of bias resistance. In the measurement of the conversion conductance of pentodes and triodes with signal-grid injection, both the ac signals shown in Fig. 29 are applied to the signal grid.

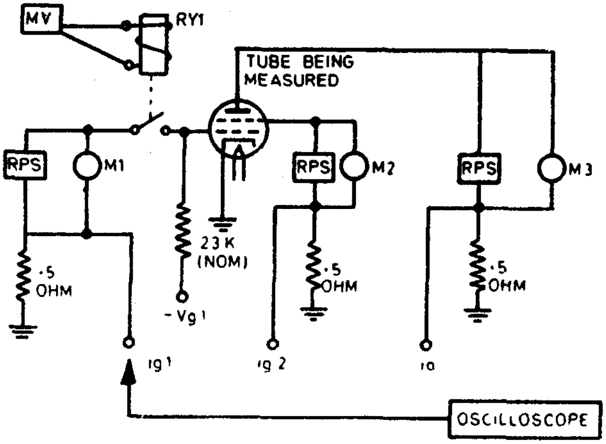
4.11.6.8 *Precautions* — The 50 Hz voltage shall be reasonably sinusoidal. Voltage regulators of the saturation type should be avoided because of waveform distortion.

The regulation of the screen supply should be such as to have a negligible effect upon the current regardless of the phase of the signal voltage. For example, the use of a screen source having a dc resistance of 10 000 ohms in measurements on ordinary converter tubes may cause plus or minus 0·6 percent voltage variation with a resultant error in conversion conductance reading of over 15 percent.

4.12 Current Division

4.12.1 *Method A (Long Pulse)*

4.12.1.1 The dc voltages applied to the tube elements shall be as shown in the individual detail specification. The pulse duration (t_p) shall be 1 000 μs minimum, or as specified. The pulse recurrence rate (pra) shall be 11 ± 2 pulses per second or as specified. The grid voltage pulse is essentially a square wave and its magnitude is adjusted as required for either procedure (A) or (B). The input wave shape shall be a t_r and a t_f of 25 μs maximum each, and slope of the top of the pulse may not be greater than 0·5 percent, with a ripple not exceeding 0·1 percent. The basic test circuit is shown in Fig. 30 with the general specification of the pulse used shown in Fig. 31.



NOTE 1 — Regulated power supplies (RPS) shall be capable of maintaining the voltage steady over the duration of the pulse.

NOTE 2 — The magnitude of the grid voltage pulse (V_{g1}) shall be as read on meter M1 which reads V dc.

NOTE 3 — Meters shall be accurate to within 1 percent.

NOTE 4 — Ry_1 shall be a mercury wetted contact type relay or equivalent.

NOTE 5 — Current monitoring resistors may be sorted out.

NOTE 6 — Peak reading devices which measure pulse amplitude may be used in place of the oscilloscope. The amplitude of the pulse leading edge shall be measured within 30 microseconds.

FIG. 30 BASIC TEST CIRCUIT

4.12.1.2 The magnitude of the grid voltage pulse is adjusted to produce the specified anode current at the leading edge of the pulse, excluding any spike. The magnitude of the drive voltage pulse (V_{g1}) relative to zero level is read and must fall within the limits shown in the detail specification. When shown as requirements, the magnitudes of the grid current (s) i_{g1}, i_{g2}, i_{g3} and so forth, shall comply with limits shown in the detail specification.

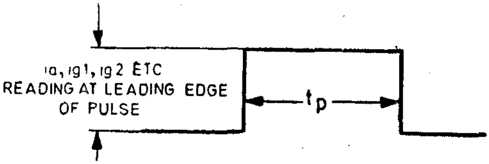


FIG. 31 GENERAL CHARACTERISTICS OF THE PULSE

4.12.1.3 The magnitude of the grid voltage pulse is adjusted to bring the grid to zero voltage level during the pulse. The magnitude of the pulse anode current (i_a) and, when shown as requirements, the grid current (s) i_{g1}, i_{g2}, i_{g3} and so forth, are read at the leading edge, excluding spike, and shall comply with the limits shown in the individual detail specification.

4.12.1.4 Pulse duration (t_p) should be adjusted to a maximum value between the specified value stated commensurate with practical limitations of the tube element dissipations.

4.12.2 *Method B (Short Pulse)*

4.12.2.1 The dc voltages applied to the tube elements shall be as specified. The pulse duration (t_p), pulse recurrence rate (prr), and type of pulse used shall be appropriate for the tube under test. The magnitude of the grid-voltage pulse is adjusted as required for either procedure (A) or (B).

4.12.2.2 The magnitude of the grid-voltage pulse is adjusted to produce the specified peak anode current (i_a). The magnitude of the peak-grid drive voltage pulse above zero level (V_{g1}) is read and should fall within the specified limits. When shown as requirements, the magnitude of the peak-grid current (s) i_{g1}, i_{g2}, i_{g3}, etc, shall not exceed the specified limits.

4.12.2.3 The magnitude of the peak-grid drive voltage pulse is adjusted to bring the grid to zero voltage level at the peak of the pulse. The magnitude of the peak-pulse anode current (i_a) and, when shown as requirements, the magnitude of the peak-grid current (s) i_{g1}, i_{g2}, i_{g3} and so forth, are read and shall comply with the limits shown in the detail specification.

4.13 Power Output

4.13.1 *Audio Power Output*

4.13.1.1 The power output of an electron tube is dependent upon the direct operating voltage applied to the various electrodes, the external load impedance in the anode circuit, and the magnitude of the exciting voltage applied to the control grid. In any case, the operating conditions are subject to the maximum safe values placed by the manufacturer upon electrode voltages, electrode power dissipation and space current drawn from the cathode.

4.13.1.2 For electron tubes normally used as Class A amplifiers under conditions such that the control grid is not driven appreciably positive with respect to the cathode, the power output is the power delivered to a resistive load with a sinusoidal input voltage applied to the grid. For tube in which the control grid is driven positive, as in Class B amplifiers special consideration shall be given to the impedance in the grid circuit and its effect on harmonic distortion.

4.13.1.3 In general, where harmonic distortion is undesirable, the power output available in any particular application will increase with the permissible percentage of harmonics. The amount of distortion that may be tolerated varies greatly in different applications; consequently no single criterion of permissible distortion is acceptable in all cases. A reference to the available power output for sinusoidal input should be accompanied by a statement of the maximum percentage of distortion present at this power output or at lower values of power output within the operating range. This percentage of distortion is expressed in terms of the total distortion, or the individual harmonic components of output current may be expressed separately as percentages of the current of fundamental frequency. Usually, the second and third harmonics will suffice, but higher order terms should be given where they are of the same order of importance as the second and third harmonics.

4.13.1.4 A circuit for the measurement of power output of a tube in a single-ended output stage is shown in Fig. 32. An iron-cored choke L is employed for shunt feed in the anode circuit; care should be exercised in its selection or design to avoid the generation of harmonics in it as a result of the non-linear and hysteretic behaviour of the iron. A commercial type harmonic analyser is recommended. The power output may be calculated by knowing the load resistance R and the rms current through it.

4.13.1.5 The techniques used in the measurement of power output in push-pull operation are basically similar to those employed for single-ended operation, but some additional precautions should be observed. Care should be taken to ensure that the input transformer produces voltages that are equal, opposite in phase and without harmonics. These requirements are most readily met if a transformer is of adequate size for the power required and has low leakage inductance between windings.

When the grids are driven positive, as in Class AB or Class B operation, the effective resistance and impedance of the driving source shall be specified. The effects of regulation of the power supply voltages, including grid bias are particularly important in Class AB and Class B operation. If a centre-tapped iron-cored choke is employed for shunt-feeding the anode circuit, it should be designed so that the two halves of the winding have the same dc resistance, the leakage inductance between the two halves of the winding is low and the iron core is of adequate size and correct material to avoid the generation of harmonics. The measurement data about push-pull stages using self-bias should state whether the cathode resistor was by-passed.

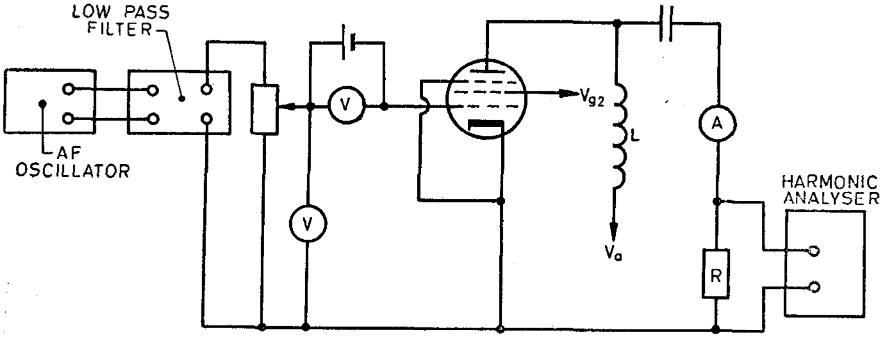


FIG. 32 CIRCUIT ARRANGEMENT FOR MEASURING POWER OUTPUT OF A TUBE

4.13.2 *R. F. Power Output (Negative Grid Power Tubes)*

4.13.2.1 This test is to measure that part of the total radio-frequency output power flowing from the tube output terminals into the matched resistive load. A recommended schematic is shown in Fig. 33.

4.13.2.2 *Method A (for power amplifier)*

The grid bias shall be set to the specified value or adjusted for maximum output. If power gain is to be determined, grid bias shall be set as specified.

The anode and screen supplies are applied and adjusted to the specified values.

The tuning and output coupling shall be adjusted to obtain the highest possible output power.

If specified, the driving power, or input RF power given by the difference between the forward and reflected values measured by the reflectometer, shall be set as specified.

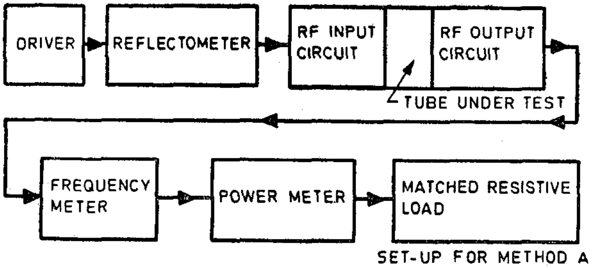
The following shall be specified in the relevant detail specification:

a) Electrode voltage,

b) Electrode currents or ranges of currents,

c) Frequency of the RF output.

d) Maximum allowable driving power.



(Neutralization of inherent feed back may be accomplished by known techniques to maintain stable tube operation)

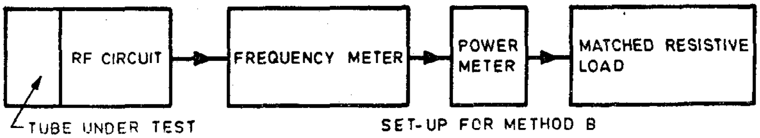


FIG. 33 MEASUREMENT OF RF OUTPUT POWER NEGATIVE GRID POWER TUBES

4.13.2.3 *Method B (for self-excited oscillator)*

The electrode voltages shall be adjusted to the specified values and the grid current is observed to ensure that it does not exceed the specified value.

The anode to grid feedback, and the output coupling shall be adjusted to obtain the highest possible output at the specified values of anode and grid currents.

The following shall be specified in the relevant specification:

a) Value of grid bias resistor,

b) Electrode voltages,

c) Anode current and range of grid current, and

d) Frequency of oscillation (may be as specified or higher)

4.13.2.4 *Alternative methods*

Methods alternative to those of Methods A and B shall be similar except that the adjustment shall be made in order to obtain at least the specified value of output power, the electrode currents being within specified values.

The following shall be specified in the relevant detail specification:

a) Electrode voltages and value of grid resistor for oscillator,

b) Frequency of RF output,

c) Required level of output power,

d) Maximum value of anode current, and

e) Range limits for grid (and screen grid) currents.

NOTE 1 — Grid bias is not specified as tube is operated as Class C and the bias would vary from tube to tube.

NOTE 2 — No reflectometer is needed to measure power output if a matched resistive load is used.

4.14 Electrode Dissipation

4.14.1 *Anode Dissipation* — When the tube is operating under steady-state conditions, the anode dissipation is given by the product of mean anode current and anode voltage. In other cases, if reasonably accurate anode dissipation figures are required, thermocouple method may be used. In this method use is made of the heat radiation from the anode which is not only due to anode dissipation but also partly due to dissipation at various other electrodes. Hence the accuracy of this method depends upon the extent to which the other electrodes contribute towards raising the temperature of the anode.

4.14.1.1 The anode radiation may be collected from one side of the anode at a time by means of a conical tubing with reflecting walls and the energy focussed upon a thermocouple. The anode is then supplied with dc power under static conditions to duplicate the previous thermocouple readings and the dc power supplied will be equivalent to the anode dissipation.

4.14.2 *Grid Dissipation* — Information on grid dissipation in power tubes is important to ensure that the grid is operated below the point at which primary emission becomes excessive. The method of measurement given here is applicable only at frequencies low enough so that electron transit time is negligible. It should be borne in mind that grid dissipation is a component of, but not the same as, grid driving power.

4.14.2.1 The grid dissipation may be calculated if the peak alternating grid voltage is known. This may be measured with the help of a tube voltmeter. The product of 0·9 times the direct grid current and the peak positive excursion of the grid voltage with respect to the cathode is the approximate grid power dissipation. This method is subject to error if secondary emission is appreciable.

4.15 Measurement of Envelope Temperature

4.15.1 *Introduction* — Unless the position for the measurement of the envelope temperature of the tube is specified it should be taken at the hottest point of the envelope. The possibility that high temperature gradients may exists should be recognized in probing for the point of highest temperature. This will normally be opposite to the centre in the case of sub-miniature tubes and may be at the foot of the tube in the case of some tube with flying leads. Particular care should be taken when carrying out the temperature measurement of the tube envelope since all the known methods are liable to errors which can be significant where long life is concerned. If temperature-sensitive paints or crayons are used to check the temperature, inaccuracy might occur due to contamination by dirt or moisture or by the mixing of different colours. In such cases, it may be necessary to take note of the timing since some colour changes are very dependent on heating time. Paints and crayons which indicate the temperature by melting are less dependent on heating time and avoid subjective judgements of colour shades. Before using any temperature-sensitive methods, the manufacturer's instructions should be carefully studied. If a thermocouple or similar device is used, the errors may be caused by bad thermal contact between the tube and the thermocouple.

4.15.2 *Measurement Methods* — The methods used for measurement differ in accuracy and convenience of use depending on the particular circumstances and the manner of rating of the tubes. The following two methods are indicated for:

a) measurement of temperature at a specified point on the envelope, or

b) measurement of average circumferential temperature.

4.15.2.1 *Temperature at a point* — The measurement of temperature at a specified point on the envelope of a tube needs the use of a thermocouple. To attain the highest degree of accuracy, it is important that:

a) the thermocouple be constructed of strip or wire of small crosssection, for example, wires of the order of 0·1 mm diameter but not greater than 0·13 mm;

b) the wires adjacent to the junction should be held in good thermal contact with the tube envelope to minimize the cooling of the junction by conduction or radiation; and

c) area of contact of the thermocouple with the envelope should be as small as possible.

4.15.2.2 *Average circumferential temperature* — In this case also, thermo-couple is used and the wires of the thermocouple shall be welded to two diametrically opposite points on a close fiting phosphor bronze split ring. Such a typical ring shall have a cross-section of 2·5 × 0·5 mm and should fit tightly around the envelope. Depending on the design of the envelope and the ambient conditions, this method will give temperature readings approximately 10 to 20°C lower than the method specified in **4.15.2.1**.

4.15.2.3 In certain cases where neither of the methods described in **4.15.2.1** and **4.15.2.2** can be used, for example, where the envelope is surrounded by a screening can, it may be necessary to make use of the less accurate method employing temperature indicating paints.

4.16 Equivalent Noise Resistance

4.16.1 The main causes of noise in tubes used in intermediate-frequency (IF) and the radio-frequency (RF) amplifiers and mixers are due to shot effect and partition noise. This noise is considered to be in the same frequency band as that over which the amplifier operates. In the case of a frequency changer, it is more complex, but in practice the noise is again considered to occupy only the signal frequency band and not the image frequency band or the IF band. This noise does not include flicker effect which occurs mainly in the audio-frequency band and which may extend up to about 1 MHz neither does it include grid noise effects which become significant at frequencies above 20 MHz. The results of measurement within the frequency range of 1 to 20 MHz will be substantially the same.

4.16.1.1 The method of measurement specified is not directly applicable to frequency changer tubes unless the input circuits are modified to restrict to the specified input bandwidth.

4.16.1.2 Measurement of equivalent noise resistance is not applicable to transmitting tubes.

4.16.2 A typical set-up, with which equivalent noise resistance of a tube may be measured, is given in Fig. 34.

4.16.3 With the noise diode filament supply turned off and the attenuator short-circuited, the gain of the amplifier, whose bandwidth should lie well within the specified frequency limits, is adjusted to give a convenient reading on the indicating devise of the noise produced by the tube under test.

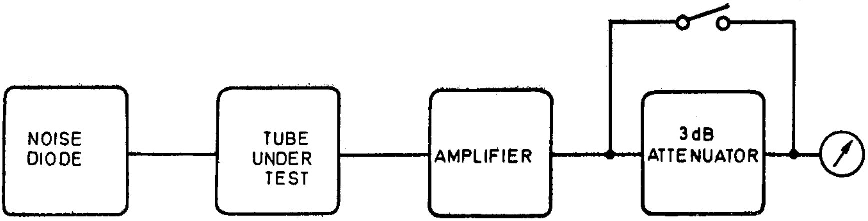


FIG. 34 SET-UP FOR MEASURING EQUIVALENT NOISE RESISTANCE

4.16.4 The noise diode and the attenuator are then switched into circuit and the current of the noise diode is adjusted until the reading on indicating device is the same as the previous one. Under this condition, provided that the noise contribution of the amplifier following the tube can be neglected, the following equation applies:

$$R_{eq} = \frac{e. I_d. R^2_s}{2kT} - R_s$$

where

R_{eq} = equivalent noise resistance;
e = charge of the electron = $1{\cdot}60 \times 10^{-19}$ coulombs;
I_d = current through the noise diode, in amperes;
R_s = the load resistance of the noise diode (ohms);
k = Boltzmann's constant = $1{\cdot}38 \times 10^{-23}$ joules per degree kelvin; and
T = absolute temperature of the noise diode resistance in degree kelvin.

4.16.4.1 R_{eq} is normally quoted for the value $T = 290$°K.

4.16.4.2 If the temperature of the noise diode resistance K differs appreciably from 290°K, a correction should be made.

4.16.5 Disadvantages of this method of measurement are as follows:

a) The input capacitance of the tube being measured has a shunting effect upon the noise diode resistance; usually this effect is small for values of load resistance up to about 500 ohms.

b) Difficulties may arise due to feedback through the anode to grid capacitance of the tube being measured.

4.16.6 A suitable circuit diagram for the first two stages (noise diode coupled to tube under test) is given in Fig. 35.

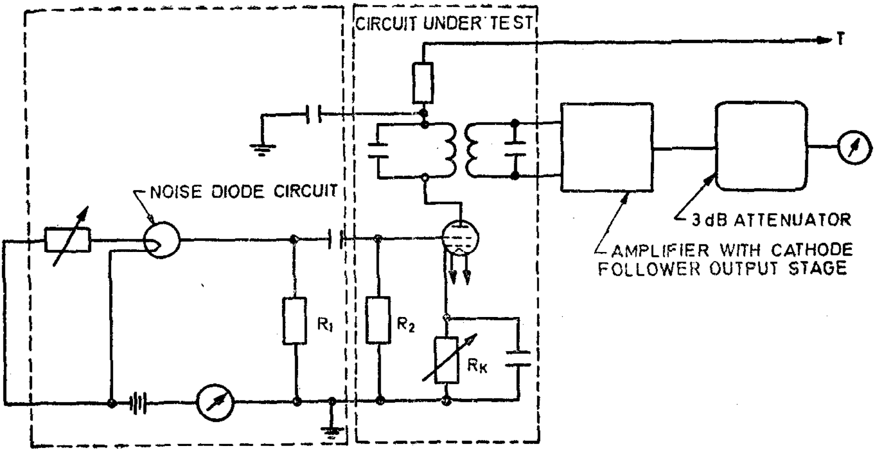


FIG. 35 TYPICAL CIRCUIT DIAGRAM FOR MEASURING EQUIVALENT NOISE RESISTANCE

4.16.6.1 The tube under test, is first set up to the required current conditions by adjustment of the cathode resistor R_k. Typical values of the resistors R_1 in the diode circuit and R_2 in the grid circuit of the tube being measured are:

100 Ω and 1 M Ω respectively for values of *R*eq between 100 Ω and 2 000 Ω

700 Ω and 1 M Ω respectively for values of *R*eq between 2 000 Ω and 100 000 Ω

4.16.6.2 In carrying out measurement in this circuit, the following precautions should be observed:

a) The centre frequency of the pass-band of the amplifier and its associated circuits should be sufficiently high to avoid the effect of flicker noise and sufficiently low to avoid the effect of induced grid noise.

b) The amplifier and the indicating device following the attenuator should be capable of handling, without distortion, signals whose peak value is approximately ten times that of their greater mean value.

c) In view of the high gain necessary in the amplifier circuit and of the low signal level of the order of one microvolt encountered in this measurement, care should be taken to provide adequate screening to avoid unwanted pick-up and feedback.

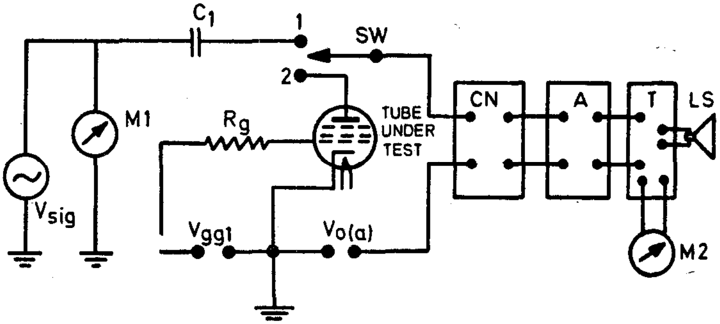
d) In the case of tubes having a high mutual conductance and a relatively large anode-gride capacitance C_{ag}, the difficulties caused by unwanted feedback may have to be eliminated by the use of normal neutralization techniques.

e) If the temperature of the noise diode resistor is different from 290°K, its value should be noted and a correction applied.

f) All resistors associated with the input circuit of the tube under test shall be of a low noise type.

4.17 Audio Frequency Noise and Microphones

4.17.1 The tube under test shall have the specified operating potentials applied to all elements and shall be tested in an acoustic chamber, with a 180 mm (approximately) or 200 mm (approximately) diameter speaker having a nominal free-air-cone-resonance of 70 Hz or lower, and a power rating of 5 watts, minimum, mounted on the 280 by 450 mm closed end and facing inward, and the tube test socket mounted approximate 80 mm from the opposite open end. The top and sides of the acoustic chamber shall be free and clear of all material that might affect the acoustic characteristics. The anode of the tube under test shall be coupled through a 0·1 μF capacitor to an audio amplifier having an input resistance of approximately 100 000 ohms and a response characteristic between 60 and 5 000 Hz, flat within ± 2·0 dB of the 400 Hz response with a resistor load substituted for the speaker. The power amplifier shall be capable of delivering 5 watts with less than 10 percent distortion. The speaker shall be coupled to the output of the amplifier so as to present rated load to the amplifier. The output indicator shall be a standard VU meter. The VU meter with its attenuator shall be bridged across a suitable tap on the output of the amplifier. The VU meter may have the dial calibrated in electrical or arbitrary units, but the attenuator shall be designed to retain the ballistic characteristic specified for the VU meter. The callibrated points used for setting the amplifier gain shall be the rejection points and shall be determined for each test set on the basis of the power in the resistor load only. At 400 Hz and 50 mW the resistor shall have been adjusted to the same impedance as the voice coil for which it is substituted. The amplifier gain shall be adjusted (without the tube in the test socket) to give the specified output with the specified calibration voltage at 400 Hz applied to the anode terminal of the tube test socket. The calibrating voltage shall be removed and the tube under test inserted (*see* Fig. 36). When operating under the above conditions, the tube shall be tapped, with a mallet on mechanical tapping device, at least three times in each of two directions which are at right angles to each other.



A = Audio amplifier
C_1 = 4 μF capacitor (*Min*)
CN = Coupling network
V_{sig} = 400 Hz signal source
LS = Loudspeaker
*M*1 = Voltmeter
*M*2 = Output meter connected to Tad with rated impedance

R_g = Grid resistor
SW = Transfer switch
1 — Calibrate
2 — Test
T = Tapped auto transformer

FIG. 36 AUDIO FREQUENCY NOISE AND MICROPHONICS TEST

4.17.2 Objectionable noise or microphonism shall be defined as:

a) Background noise, sustained microphonic, or oscillation over 2 seconds in duration having greater than ½ mW output power level.

b) Clicks or scratchy noise of any sort.

4.17.3 When operating under the above conditions, no objectionable noise or microphonism shall be evident either with the tube at rest or when it is tapped.

NOTE — The ballistic deflection as indicated by the output meter shall not exceed the maximum output specified.

4.18 Hiss and Hum

4.18.1 *General* — Measurement of hiss and hum is not applicable to transmitting tubes.

4.18.1.1 *Hiss* — The hiss is expressed as an equivalent rms grid voltage and should be measured by a device reading true rms voltage. Unless otherwise stated, the measuring circuit should have a frequency characteristic which does not deviate by more than 3 dB from its response at 400 Hz over the range between the half-power points 25 and 10 000 Hz.

The rate of decrease outside the frequency range should be approximately 6 dB per octave. The operating conditions of the tube shall be clearly specified, including the impedance of the external connections to all electrodes.

4.18.1.2 *Hum* — The hum is expressed as an equivalent rms grid voltage and should be measured by a device reading tube rms voltage.

The ac filament heater supply should be nominally 50 Hz, the harmonic content of which shall be known.

The hum should be measured through a filter having an agreed passband. This may be either a low-pass filter having a sharp cut-off at approximately 600 Hz or for certain purposes an ear filter. This latter filter is useful where the actual audible result of the hum is required to be assessed, although in this case, where the hum content is very low, the figure obtained may be influenced by the presence of hiss.

The operating conditions of the tube being measured shall be clearly specified, including the impedances of the external connections to all electrodes and any ac or dc voltage between filament or heater and the cathode.

4.18.2 *Measuring Circuit* — Fig. 37 shows the block diagram of the measuring circuit used for these measurements.

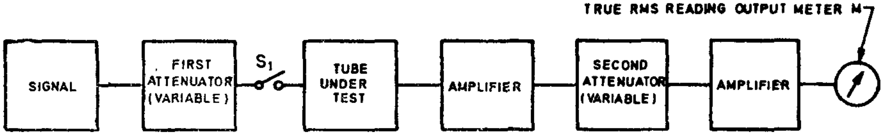
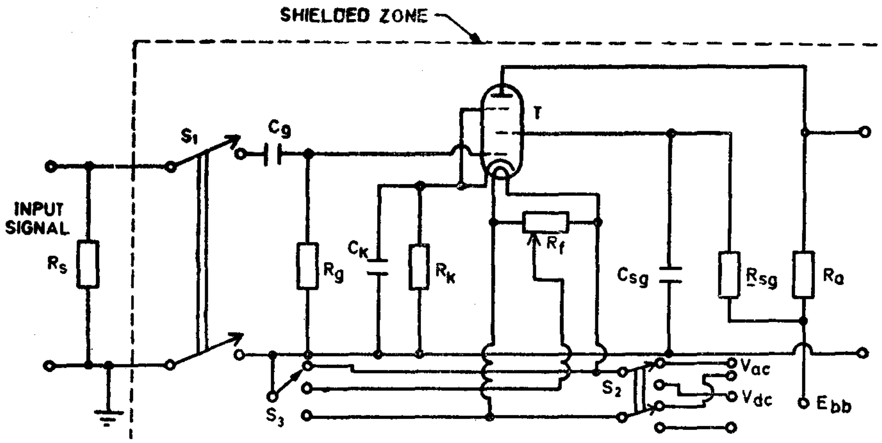

TRUE RMS READING OUTPUT METER M
SIGNAL
FIRST ATTENUATOR (VARIABLE)
S_1
TUBE UNDER TEST
AMPLIFIER
SECOND ATTENUATOR (VARIABLE)
AMPLIFIER

FIG. 37 BLOCK DIAGRAM OF HISS AND HUM MEASURING CIRCUIT

A typical circuit diagram is shown in Fig. 38.

4.18.3 *Measuring Procedure*

4.18.3.1 *Calibration of the amplifiers* — The specified dc supply voltage should be applied to the heater by means of the switch S_2. A known signal voltage E_s (approx 3 mV) from the 400 Hz signal generator should then be applied to the control grid of the tube under test keeping the attenuation of the second attenuator at a sufficiently large value D_0 expressed in decibels. The deflection M of output meter should be adjusted to a certain value E_0 (say 0 dB) by the adjustment of gain of the second amplifier.



T = Tube being measured.
R_a, R_f, R_g, R_k, R_s, R_{sg} = Resistors (values to be stated. Resistors R_a and R_g should be of a type which does not introduce additional noise).
C_q, C_k, C_{sg} = Capacitors (values to be stated).
S_1, S_2, S_3 = Switches.
E_{bb} = Anode dc voltage source (value to be stated).
V_{ac} = AC heater voltage source (value to be stated).
V_{dc} = DC heater voltage source (the same value ac V_{ac}).

FIG. 38 TYPICAL CIRCUIT FOR MEASURING HISS AND HUM

4.18.3.2 *Measurement of hiss noise-voltage* — After the calibration process mentioned in **4.18.3.1**, the input signal voltage should be removed by opening the switch S_1. The deflection M of the output meter should be again adjusted to the same value E_o (say 0 dB) as in **4.18.3.1**, by decreasing the attenuation of the second attenuator to a value D_1 expressed in decibels. The value of the hiss noise-voltage E_{hiss} expressed in decibels (with respect to an arbitrarily chosen reference voltage) at the input terminal of the tube being measured is found from the following formula:

$$20 \log \frac{E_{hiss}}{E_s} = - D_o + D_1$$

The above equation holds true only if the hiss is negligible when compared to the calibrating signal. A reasonable accuracy to be expected is approximately 10 percent.

4.18.3.3 *Measurement of hum noise-voltage* — After the measurement of the hiss noise-voltage, the filter (*see* **4.18.1.2**) should be switched in circuit and the specified ac voltage should be supplied to the heater by means of the other contacts of the switch S_2. The deflection M of the output meter should be again adjusted to the same value E_0 as in **4.18.3.1** by changing the attenuation of the second attenuator to a suitable value D_2. The value of the hum noise-voltage E_{hum} expressed in decibels (with respect to an arbitrarily chosen reference voltage) at the input terminals of the tube being measured is found from the following formula:

$$20 \log \frac{E_{\text{hum}}}{E_8} = D_0 + D_2$$

The above equation holds true only if the hum is negligible when compared to the calibrating signal. A reasonable accuracy to be expected is approximately 10 percent.

4.18.3.4 *Measurement of hiss and hum noise-voltage* — Combined hiss and hum may be measured in accordance with **4.18.3.3** above, but with the heater of the tube connected to an ac supply.

4.18.4 *Precautions* — The following precautions are applicable:

a) Each measurement should be made at least three minutes after the application of the heater voltage.

b) It is important that the ripple in the supply voltages be negligible.

c) If an internal shield exists in the tube under test, it should be grounded.

d) Care should be taken to shield the tube under test from stray magnetic and electric fields.

e) Unless otherwise specified, it is customary to ground the lower numbered heater pin. The switch S_3 allows either side or any other point of the heater to be grounded.

f) The socket used for the measurements has considerable influence on the results obtained owing to stray capacitance and leakages. Therefore, for standardization and comparison purposes, a fully shielded socket should be used. It is recognized that, because of differences in commercially available sockets, the hum and hiss produced by a particular tube in an equipment may be different from the values obtained by the recommended method of measurement.

4.19 Conversion Resistance

4.19.1 For a resistance-ratio method a simplified diagram for the measurement of the conversion resistance is given in Fig. 39. The diagram does not include the power sources required for operating the tube under test.

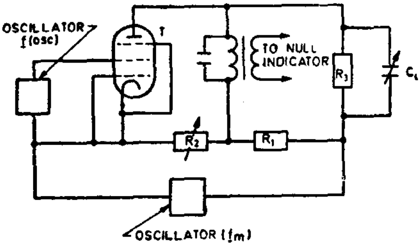


FIG. 39 SIMPLIFIED CIRCUIT FOR MEASUREMENT OF CONVERSION RESISTANCE

4.19.2 The oscillator voltage V_{OSC} is applied to the same grid as that to which it is applied for the actual function of the tube. This is a special grid in the case of multiplicative mixing, whereas the signal grid serves as a mixer grid also in the case of additive mixing. The signal voltage is assumed to be small for the determination of all mixer characteristics; therefore, its influence can be neglected for the measurement of the conversion resistance and only the oscillator voltage V_{OSC} is to be taken into account.

4.19.3 The frequency f_m at which the conversion resistance is measured should be low enough with respect to the oscillator frequency f_{OSC}, in order not to influence the measuring result and to allow adequate separation in the output circuit.

4.19.4 Under conditions of balance, the conversion resistance $r(\mathrm{c})$ is derived from the equation:

$$r(\mathrm{c}) = \frac{R_2 \times R_3}{R_1}$$

4.20 Intermodulation Products in Transmitting Tube

4.20.1 Intermodulation is unwanted generation of power at new non-harmonic radio frequencies as the result of simultaneous application of power at two or more frequencies to a non-linear amplifying electron device. Measurement of the level of the intermodulation products provides an indication of the distortion caused to an input signal by a tube as the result of non-linearity of its transfer characteristics.

4.20.2 *Methods of Measurements*

4.20.2.1 The two-frequency or two-tone method is the recommended method for measuring intermodulation products of transmitting tubes. Two equal amplitude radio frequency signals applied simultaneously to the input of the amplifier tube, produce, at the output, fundamental components of substantially equal amplitude at radio frequencies f_1 and f_2 and in addition, intermodulation products.

4.20.2.2 The frequencies of the intermodulation products are equivalent to $pf_1 + qf_2$ and $pf_1 - qf_2$ wherein the coefficients p and q are any positive integers.

4.20.2.3 Only the intermodulation components having integral coefficients whose difference is unity ($p - q = 1$) fall within the passband of the output circuit or near enough to it to have an appreciable amplitude.

NOTE — In high-power transmitting tube measurements, care should be taken to ensure that no intermodulation products originate in the measuring equipment because of overloading. This may require careful shielding of the measuring apparatus.

4.20.2.4 Furthermore, if modulation techniques are used to develop the two frequencies f_1 and f_2, care should be taken to ensure:

a) that no modulation products arise in the low-frequency equipment or during the process of modulation;

b) that the modulation frequencies are neither harmonically related nor related in such a fashion as to produce intermodulation having frequencies so near to each other that they cannot be resolved.

4.20.3 *Choice of Frequencies*

4.20.3.1 The two input frequencies should be chosen with care so that the intermodulation products fall in clear channels.

4.20.3.2 The preferred frequencies lie between 1 MHz and 10 MHz.

4.20.3.3 The frequency separation of f_1 and f_2 is usually between 400 Hz and 3 000 Hz.

4.20.4 *Basic Circuit*

4.20.4.1 A recommended circuit is shown in Fig. 40.

4.20.4.2 No negative feed back is to be used in the measurement circuit except that the amplifier may be neutralised if necessary for stable operation.

NOTE — Feedback may be used in equipment operation to compensate for non-linearity but it shall not be used in the tube measurements.

4.20.4.3 The power supplies to the tube being measured shall be adequately decoupled and well regulated.

4.20.4.4 This applies particularly to the grid supplies which shall be regulated to ± 1 percent unless otherwise stated.

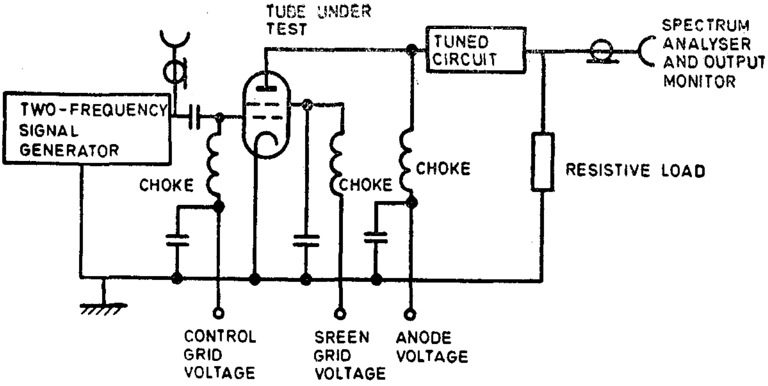


FIG. 40 BASIC CIRCUIT FOR MEASUREMENT OF INTERMODULATION PRODUCTS IN TRANSMITTING TUBES

4.20.4.5 As the amplifier input impedance varies with the drive level the internal impedance of the driving stage should be less than 10 percent of the input impedance. The drive impedance shall be stated. The spectrum analyser which is coupled to the output circuit shall be capable of clear resolution of all intermodulation products when 60 dB below either fundamental signal.

4.20.5 *Measurements* (*Peak Envelope Power*) (*P. E. P.*)

4.20.5.1 In making measurements, the sequence below shall be followed:

a) No negative feedback shall be used in the measurement unless required for stable operation.

If neutralisation is needed the fact shall be stated; any adjustment shall be made with no anode current flowing, preferably under cold conditions and no further adjustment shall be made thereafter.

b) The stated conditions are adjusted to without r.f. drive. After the no signal current (I_{ao}) is stable, the next step is followed.

c) Single-frequency r. f. drive is applied. Keeping screen current within the allowed range, drive level and the variable parameters are adjusted simultaneously (tuning and coupling in the output, etc). Thereafter, these adjustments remain fixed.

d) Single-frequency input is reduced by 6 dB and tow-frequency signal is switched. Keeping the input signals at equal amplitude, the level of drive is adjusted to achieve the same value of peak envelope power as before.

On the spectrum analyser the intermodulation ratio is measured identifying the order as necessary.

e) The intermodulation ratio is observed whilst the level of drive is varied. The intermodulation ratio is measured at the highest level of intermodulation product and the tube operating conditions including load impedance and Q factor of the output circuit, are stated.

4.21 Filament Burnout

4.21.1 The purpose of this test is to ensure that the filament suspensions is designed such that when the filament opens, no permanent short circuit occurs between the filament and any element carrying anode voltage.

4.21.2 Raise the Vf until the filament opens. Test for shorts from the filament to elements carrying V + voltage.

4.21.3 If a short circuit is indicated it shall not pass a current in excess of five times the rated filament current without burning out the short circuit.

4.21.4 This is a destructive test.

4.22 Bump

4.22.1 This test is normally used to check the brittleness of the filaments in tubes having thoriated tungusten filaments and to check the quality of ceramic insulators.

4.22.2 Each tube shall be mounted in a vertical position in the test equipment. No electrical potential shall be applied to the tube during the test. The test shall be carried out in accordance with the methtod specified in IS : 589-1961*.

4.23 Mechanical Shock

4.23.1 The object of this test is to determine the structural integrity and performance of tubes when they are subjected to mechanical shock. The test shall be carried out in accordance with the method specified in IS : 589-1961* in addition to the condition specified below.

4.23.2 *Conditions of Application of Shock*

4.23.2.1 Shock impulses shall be applied to the tube in four directions successively, that is:

a) With the main axis of the tube and the major cross-section of the electrode assembly at right angles to the direction of the accelerating force;

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*Basic climatic and mechanical durability tests for components for electrical equipment (*revised*).

b) With the main axis of the tube at right angles to and with the major cross-section of the electrode assembly parallel to the accelerating force;

c) With the main axis of the tube parallel to the direction of the accelerating force and with the principal base of the tube facing the accerlating force; and

d) With the main axis of the tube parallel to the direction of the accelerating force and with the principal base of the tube facing away from the accelerating force.

4.23.2.2 The tube to which the shock is to be applied is suitably clamped so that the shock is transmitted to the whole tube. It must not be applied via the base pins only. This may be achieved either by clamping the tube or by embedding in wax in a rigid container. Care must be taken to ensure proper transmission of shock to the tube.

4.23.3 *Measuring Conditions*

4.23.3.1 Tubes shall be subjected to shock in accordance with one or more of the defined conditions which may be as follows:

a) with the tube cold, that is no voltages applied;

b) with defined voltages applied to the electrodes; or

c) with the required filament or heater voltage applied and short-circuit indicators connected to the various electrodes (*see* Appendix A).

4.23.4 The tube shall meet the laid down specification before and after the test.

4.24 Vibration

4.24.1 The purpose of this test is to determine the effect on component parts of vibration in the specified frequency range. The test shall be carried out in accordance with the method specified in IS : 589-1961* in addition to the conditions specified below.

4.24.1.1 *Fixturing and control points* — For each axis of vibration, the tube under test shall be rigidly mounted on a suitable fixture that is free from mechanical resonance over the test frequency. The test fixture shall not cause attentuation of the energy level exhibited at the platform using accepted standards of measurements for calibration of the shock level and time duration. The tube may also be mounted directly on the vibration table. If a fixture is used, it shall be so designed as to transmit the acceleration along the required axis. The vibration input shall be monitored and controlled at a point on the fixture close to the attachment points of the tube.

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*Basic climatic and mechanical durability tests for components for electrical equipment (*revised*).

4.24.1.2 *Low-frequency (25 Hz) vibration* — The tube shall be rigidly mounted on a table vibrating with simple harmonic motion at a frequency of 25 ± 2 Hz with a fixed amplitude of 1·016 ± 0·063 mm (total excursion of 2·032 ± 0·127 mm). Each tube shall be vibrated in positions '*X*' and '*Y*', except that if the cumulative result of tests on 50 or more tubes of a construction shows that more than 75 percent of the tubes have higher output voltages in one position, subsequent measurements shall be taken only in the position giving the higher readings. The voltages specified in the detail specification shall be applied to the tube during vibration. The value V_a under test conditions shall be regarded as $V_{b(a)}$ and shall be applied to the tube through the specified resistor, $R_{(a)}$. The impedances of anode and screen voltage supplies shall not exceed that of a 40 μF capacitor at 10 Hz (Preconditioning of the tube at these voltages is permissible). The value of the alternating voltage V_a (rms) produced across the resistor (R_a) as a result of vibration shall be measured with a suitable device. This device shall have an appropriate voltage range and shall have the ability to measure with an error of less than 10 percent, the rms value of a sine wave of voltage of all frequencies from 20 to 5 000 Hz. Thermal or VU meters may be used provided the shunting effect on the anode load does not result in error greater than the 10 percent allowed above. Unless otherwise specified, each tube shall be vibrated for a time necessary to obtain a stable reading of output voltage or for a maximum period of 30 seconds in any one position. The stable reading shall not exceed that specified in the detail specification. However, if at the end of 30 seconds, the average value of the meter reading exceeds 50 percent of the maximun specified voltage and is increasing, the tube shall be vibrated for a total time of 3 minutes, and the tube rejected if the average value of the meter reading at the end of this period exceeds the maximum specified voltage. When this test is conducted no measurement is made of output voltage; each tube shall be vibrated for 60 seconds each in positions '*X*' and '*Y*'. The test shall not result in tap or permanent shorts or defects which will cause the tube to be inoperable.

4.24.1.3 *High-frequency (50 Hz) vibration* — The test shall be conducted as specified in clause **4.24.1.2**, except the frequency of the vibrating table shall be 50 ± 2 Hz. Upon completion of the test, the tube shall comply with the criteria specified in **4.24.1.2**.

4.24.1.4 *Operation vibration* — The tube shall be vibrated in accordance with **4.24.1.2** with the specified operating conditions applied. A test load shall be arranged to pick up some power output from the tube. If the load is not vibrated with the tube, it shall be arranged so that the frequency pulling of the tube is negligible compared to the variation in frequency due to the vibration of the tube. The total radio frequency spectrum, including any permanent change in frequency shall not exceed the limit specified in the detail specification. For klystrons, the test load, as seen by the tube, shall be as specified in the detail specification. Spectrum bandwidth determination shall be made during the test, with the operating conditions held unchanged.

4.24.1.5 *Non-operating vibration* — The tube shall be vibrated at the specified frequency and acceleration in accordance with **2.24.1.2**. The conditions of operation before and after vibration including the adjustment of the tunes mechanism and reflector voltage shall remain unchanged. The difference between the oscillation frequencies before and after vibration shall not exceed the limit specified.

4.24.1.6 *Sweep-frequency vibration* — The tubes shall be fastened rigidly to the vibration platform and vibrated with simple harmonic motion over a frequency range of 50 to 2 000 Hz at peak acceleration value specified in the detail specification. If not specified, the peak acceleration shall be 100 m/sec^2. The acceleration over the frequency range shall be within 10 percent of the referenced acceleration at 100 Hz. At all frequencies from 50 to 2 000 Hz the total harmonic distortion of the acceleration waveform shall be less than 10 percent. The frequency shall increase from 50 to 2 000 Hz with approximately logarithmic progression versus time and shall require 4 minutes minimum, 5 minutes maximum, to traverse the range. Each tube shall be vibrated in positions X and Y, except that if the cumulative results of tests on 50 or more tubes for given construction show that more than 75 percent of the tubes have a higher output voltage on one position, subsequent measurements need only be taken in the position giving the higher readings. For special construction tubes, vibration positions shall be indicated in the detail specification.

Receiving tubes — Receiving tubes shall be tested in accordance with as mentioned above, except that the frequency range shall be traversed in 1 minute minimum, 3 minutes maximum. The specified voltages shall be applied to the tube during vibration. The value of V_a under test conditions shall be regarded as $V_{b(a)}$ and shall be applied to the tube through the specified resistor R_a. The value of the alternating voltage, $V_{a(rms)}$ produced across the resistor R_{a2} as a result of vibration, shall be measured with a suitable device. This device shall have an appropriate voltage range and shall have the ability to indicate with an error of less than 10 percent the rms value of sine wave at all frequencies as specified below. The voltage V_a (rms) shall be capacitance coupled to the measuring system consisting of cables, amplifier, low-pass filter, and indicator. Input impedance of the measuring system shall have a minimum value of at least 10 times the resistor, R_a at 10 kHz. Combined frequency response from the capacitor input through the amplifier and filter shall be flat within $\pm$ 1 dB from 50 Hz to 10 kHz, as referenced at 1 kHz shall be down 10 $\pm$ 2 dB at 15 kHz and down 20 $\pm$ 3 dB at 20 kHz. The impedance of the anode and screen voltage supplies shall not exceed that of a 40 μF capacitor at 10 Hz. The value of V_a (rms) shall not exceed the limit specified at any point in the sweep-frequency range nor shall this result in open circuits, permanent shorts, or tap shorts.

4.24.1.7 *Sweep-frequency vibration fatigue* (*destructive test*) — The tubes shall be fastened rigidly to the vibration platform and vibrated with simple harmonic motion over a frequency range of 50 to 2 000 Hz at a peak acceleration value of 100 m/sec^2. The acceleration over the frequency range shall be within ± 25 percent of the referenced acceleration at 50 Hz. The frequency of vibration shall be varied from 50 to 2 000 Hz and back to 50 Hz with the period of the sweep cycle being 10 minutes minimum to 20 minutes maximum. The tubes shall be vibrated for a total of 6 hours, that is, 2 hours in each of three planes, *X*, *Y* and *Z*. For special construction tubes, vibration position shall be specified in the detail specification. Only rated filament or heater voltage shall be applied. Tubes which show one or more of the following defects shall be considered failures:

a) Tubes which show permanent or tap shorts or open circuits following sweep-frequency fatigue test.

b) Tubes which do not comply with post-sweep-frequency vibration fatigue limits as specified in the detail specification.

4.24.1.8 *Variable-frequency vibration* — The tubes shall be vibrated under the conditions specified for low-frequency vibration and position *Z* shall be added. The tubes shall be vibrated at a constant amplitude in each of three positions through the frequency range from 10 to 50 Hz and back to 10 Hz. The time for gradually covering the range from 10 to 50 Hz and back to 10 Hz shall be 3 to 15 minutes. Each tube shall be vibrated for 60 seconds at the frequency which gives the maximum vibration output voltage in each of the three positions. If at the end of 60 seconds, the vibration output is increasing, the vibration shall be continued until there is no further increase. The tubes shall not show vibrational output in excess of the maximum limit specified. The test shall not result in tap or permanent interelectrode shorts or defects which cause the tube to be inoperable.

4.24.1.9 *Vibration-fatigue test* (*destructive test*) — The tube shall be rigidly mounted on a table vibrating with simple harmonic motion at a frequency of 25 ± 2 Hz with an amplitude of 1·02 ± 0·06 mm (total excursion of 2·04 ± 0·12 mm) or any equivalent combination of frequency and excursion resulting in 25 m/sec^2 applied to the tube under test. The tubes shall be vibrated for a total of 96 hours, 32 hours in each of three positions, *X*, *Y* and *Z*. Only rated filament or heater voltage shall be applied. Tubes which show one or more of the following defects shall be considered failures:

a) Tubes which show permanent or tap shorts or open circuits following vibration-fatigue test.

b) Tubes which do not comply with post-vibration-fatigue limits specified in detail specification.

4.25 Life Tests

4.25.1 *Cathode Interface Life*

4.25.1.1 *Measurement conditions*

a) The tube measured shall be operated under the conditions spcified in detail specification.

b) Heater voltage shall be controlled within 1 percent of the value specified.

c) Preheat by applying the specified heater voltage used for the measurement for not less than 5 minutes.

d) Life-tested tubes shall not be subjected to any other electrical measurements between the end of the life test and interface test.

e) When testing multisection tubes, the opposite sections may be grounded, cutoff, or floating.

f) If the anode current specified in detail specification cannot be obtained on an individual tube, the interface measurement shall be made at zero bias.

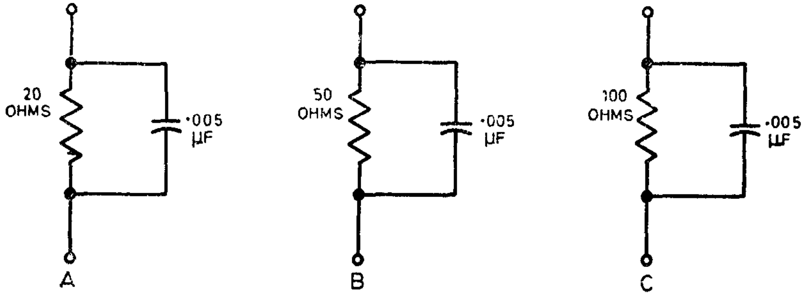
4.25.1.2 The tubes shall be operated for 500 hours with 110 percent of normal heater voltage applied and with other electrodes disconnected. The tubes shall then be measured for cathode interface impedance. The readings of cathode interface resistance shall not exceed the specified life-test final measurements. This is a destructive test.

4.25.1.3 *Impedance test*

a) *Equipment* — Interface impedance may be measured by any equipment capable of meeting the calibration requirements specified below. The equipment shall be capable of measuring the calibration network to within ± 15 percent of the R_1 value given in the calibration network of Fig. 41.

b) *Calibration* — Calibration shall be performed by connecting the calibration networks in series with the cathode of an interface free tube operated at a maximum of 2 500 micromhos transconductance. Any tube type, capable of the specified transconductance, is satisfactory of this calibration. The calibration procedure need be performed using only one tube type.

c) To determine whether the calibration tube is interface free, use is made of the temperature sensitive characteristics of the interface resistance. With the calibration network in series with the cathode of the tube, interface resistance is measured at 20 percent lower than rated heater voltage and at 20 percent higher than rated heater voltage. If the difference between the two readings is less than 10 percent, the tube shall be accepted for use as an interface-free tube.



(Resistors shall be non-inductive deposited carbon film type of 1-percent accuracy)

FIG. 41 INTERFACE NETWORKS

4.25.2 *Heater-cycling Life*

4.25.2.1 A complete cycle is made in a 2-minute period as follows: 1 minute 'on', 1 minute 'off', duration of the cycling test shall be 2 000 cycles. The heater-voltage supply shall have a regulation of not more than 3 percent (no load to steady-state load). Heater-cathode voltage shall remain on continuously. Any tube which shows an open heater open-cathode circuit, heater cathode short, or fails to meet any specified life-test final measurements for this test prior to the completion of the cycling test shall be considered a defective tube. A leakage dc current in excess of 0·5 mA between the heater and the cathode shall be considered a heater-cathode short. Sampling shall be as specified. This is a destructive test.

4.25.2.2 Electrical or mechanical defectives may be used for this test except for the following:

a) Tubes shall be within initial limits for heater or filament current.

b) Tubes shall meet the post-heater-cycling acceptance criteria.

4.25.3 *Intermittent Life*

4.25.3.1 When intermittent life-test is performed, the tubes shall be operated under the specified test conditions with the filament or heater supply interrupted periodically. There shall be 12 to 25 uniform cycles, totalling approximately 20 hours of ' on ' operation each 24 hours. The filament or heater supply shall be applied and removed instantaneously. Other potentials may be applied continuously, at the option of the manufacturer. The accumulation of the ' on ' time shall be the time considered in determining compliance with the minimum specified time value. The filament or heater-supply impedance shall not exceed 10 percent of the hot filament-load impedance. Warm up time, t_k, when specified in the detail specification as a test condition for intermittent life-test, shall be adhered to at the beginning of each ' on ' period. This is a destructive test.

4.25.3.2 *Tube intermittent life-test procedure* — Regular life-test shall be in effect initially and shall continue in effect until the eligibility criteria for the reduced-hours life-test have been met. Sampling shall be as specified. This is a destructive test.

Regular Life Test

a) Regular life test shall be conducted for 1 000 hours.

b) Regular life test acceptance shall be on the basis of the specified 500 and 1 000 hour life test final measurements.

Reduced-hours Life Test

a) Eligibility for reduced-hours life tests is established when no first sample failure due to the regular 1 000 hours life test has occurred in the preceding 3 consecutive lots.

b) Reduced-hours life test shall be conducted for 500 hours and acceptance shall be based on the 500 hour life test final measurements. Two 500 hour life test lot failures occurring in the last 3 consecutive lots shall result in loss of eligibility for reduced-hours life testing.

c) The life-test sample from the first lot accepted each month shall continue on life test for an additional 500 hours (1 000 hours total life test time). Failure of this sample to meet the 1 000 hour life test final measurements shall result in loss of eligibility for reduced-hours testing.

The life-test sample shall be read at the following times:

0 hours
+ 48 hours
500
— 24 hours
+ 48 hours
1 000 (when in force)
— 24 hours

Additional reading period may be used at the discretion of the manufacturer.

4.25.4 *Stability Life*

4.25.4.1 The purpose of this test is to determine the stability of specified characteristics during early life.

4.25.4.2 This is a test of 2 to 20 hour duration, under specified conditions, preceded and followed by measurements of one or more specified characteristics, and with maximum percentage characteristics changes specified for individual tubes. The AQL and sample size shall be as specified.

4.25.4.3 *Procedure*

a) Serially number all the tubes of the sample.

b) Record the specified characteristic measurements on the entire sample after maximum operation of 15 minutes under specified voltage and current conditions.

c) The regular stability-life test sample shall be operated at the specified stability-life-test conditions, or equivalent, for 20 ± 4 hours with an intermediate down-period reading point at 2 hours ± 30 minutes (Intermittent or continuous operation may be employed). The regular stability life test shall be in effect initially and shall continue in effect until the eligibility criteria for the reduced-hours stability life test have been met.

d) Reduced-hours stability-life-test.

   i) Eligibility for reduced-hours stability-life test shall be as follows: No lot failure due to the regular stability-life has occurred in the preceding 5 consecutive lots.

   ii) Reduced-hours stability-life test shall be conducted for 2 hours ± 30 minutes. Acceptance shall be based on the stability-life test final measurement. One lot failing the reduced-hours stability-life test shall result in loss of eligibility for the reduced hours stability-life test.

   iii) The stability-life test sample from the first lot accepted each month shall continue on stability-life test to the 20 ± 4 hours duration. Failure of this sample to meet the regular stability-life test final measurement shall result in loss of eligibility for the reduced-hours stability-life test.

iv) Life-test conditions shall be conducted as specified except that the mean electrode potentials (except heater or filament) may be established at values differing by not more than 5 percent from the specified values, provided the same average electrode dissipations are obtained that occur with the specified voltages. Fluctuations of all voltages, including heater or filament voltage, shall be as small as practicable.

v) Measurements of the specified characteristics at the specified reading periods are recorded. The measurements shall be taken immediately following the specified reading periods, or the tubes shall be preheated for a maximum of 15 minutes under specified voltage and current conditions and the characteristics immediately measured following the specified reading periods.

4.25.5 *Survival Rate-Life*

4.25.5.1 The purpose of this test is to check the maintenance of quality level in terms of early life survival.

4.25.5.2 *Procedure*

a) Samples are selected as specified.

b) Tubes are tested at 100 hours for short and discontinuity detection. When any tap-short indication is obtained, the test, shall be repeated. When any tap shorts are again obtained, the tube shall be rejected as inoperable.

c) The number of tubes defective at the 100-hour period is determined.

d) If more than the allowable number of defectives occur, the lot shall be rejected.

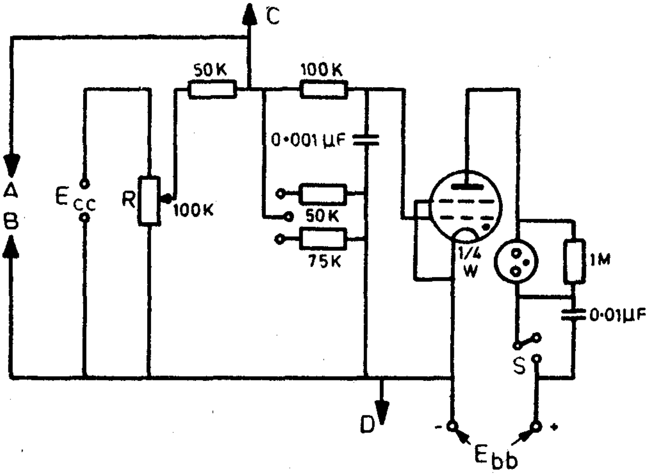
4.25.5.3 *Equivalent-conditions* — For survival-rate life test, the equivalent stability-life test conditions shall be interpreted as having the same heater voltage (V_f) and the heater cathode voltage (V_{hk}) as the stability life test; and the same interruption rate as the intermittent life test. The electrode voltages shall be such that the element dissipations are not less than 80 percent nor more than 100 percent of stability-life test anode dissipation. These voltages shall be maintained within the limits of 50 percent minimum and 200 percent maximum of specified voltages.

APPENDIX A

[*Clause* 20.3.1 (c)]

SHORT-CIRCUIT INDICATOR

A-1. A single stage of a typical thyratron-controlled indicator which may be inserted between each pair of elements in a tube for the purpose of indicating short-circuits is shown in Fig. 42.



A + *B*	To elements of tube to which shock is applied
C	To following stage
D	To preceding stage
S	Reset switch
R	Potentiometer for adjusting sensitivity

FIG. 42 SHORT CIRCUIT INDICATOR

A-2. A typical setting of this indicator is when the potentiometer *R* is adjusted to indicate a short-circuit with a 50 000 ohms resistor connected across the terminals *A* and *B* and to give no indication with 75 000 ohms connected across *A* and *B*.

INDIAN STANDARDS ON ELECTRON TUBES

IS:
1885 (Part IV/Sec 1)-1973 Electrotechnical vocabulary: Part IV Electron Tubes, Section 1 Common terms (*first revision*)
1885 (Part IV/Sec 2)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 2 X-ray tubes (*first revision*)
1885 (Part IV/Sec 3)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Mircowave tubes
1885 (Part IV/Sec 4)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 4 Cathode-ray tubes
1885 (Part IV/Sec 5)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 5 Pulse terms
1885 (Part IV/Sec 6)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 6 Noise in microwave tubes
1885 (Part IV/Sec 7)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 7 Camera tubes
1885 (Part IV/Sec 8)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 8 Photosensitive devices
2032 (Part IX)-1969 Graphical symbols used in electrotechnology: Part IX Electron tubes (other than microwave tubes)
2032 (Part XIII)-1971 Graphical symbols used in electrotechnology: Part XIII Microwave tubes
2597 (Part I)-1964 Code of practice for the use of electron tubes: Part I Commercial receiving tubes
2597 (Part II)-1967 Code of practice for the use of electron tubes: Part II Special quality receiving tubes
2597 (Part III)-1969 Code of practice for the use of electron tubes: Part III Transmitting and industrial tubes
2597 (Part IV)-1970 Code of practice for the use of electron tubes: Part IV Cathode-ray tubes
2597 (Part V)-1971 Code of practice for the use of electron tubes: Part V Rectifiers and thyratrons
2684 (Part I)-1972 Dimensions of electron tubes: Part I Miniature '9-pin type' (*first revision*)
2684 (Part II)-1972 Dimensions of electron tubes: Part II Miniature '7-pin type' (*first revision*)
2684 (Part III)-1971 Dimensions of electron tubes: Part III Octal base type
2684 (Part IV)-1971 Dimensions of electron tubes: Part IV Magnoval base type
2684 (Part V)-1972 Dimensions of electron tubes: Part V Local base type
3154-1965 Specification for X-ray tubes, diagnostic type
4096-1973 Method of measurement of optical focal spot size of X-ray tubes (*first revision*)
4147-1981 Method of measurements on conventional receiving electron tubes (*first revisivn*)
4579-1968 Method of measurements on television picture tubes
4697-1968 Method of measurements on Geiger Muller counter tubes
5323-1969 Letter symbols and abbreviations for electron tubes
5627-1970 Methods of measurements on cathode-ray display tubes
5840 (Part I)-1970 Dimensions of cathode-ray tubes: Part I Tube outlines
5840 (Part II)-1970 Dimensions of cathode-ray tubes: Part II Base type
5840 (Part III)-1970 Dimensions of cathode-ray tubes: Part III EHT Terminals
6134 (Part I)-1978 Methods of measurements on microwave tubes: Part I Common to all microwave tubes

IS:	
6134 (Part II)-1973	Methods of measurement on microwave tubes: Part II Oscilator tubes
6134 (Part III)-1973	Methods of measurement on microwave tubes: Part III Amplifier tubes
6134 (Part IV)-1977	Methods of measurement on microwave tubes: Part IV Magnetrons
6134 (Part V)-1980	Methods of measurement on microwave tubes: Part V Parasitic noise
6134 (VI)-1981	Methods of measurement of electrical characteristics of microwave tubes: Part VI Low-power oscillator klystrons
6134 (Part VII)-1981	Methods of measurement of electrical characteristics of microwave tubes: Part VII High-power klystrons
6134 (Part VIII)-1981	Methods of measurement of electrical characteristics of microwave tubes: Part VIII Gas-filled microwave switching devices
6134 (Part IX)-1981	Methods of measurement of electrical characterics of microwave tubes: Part IX Backward-wave oscillator tube — '0' type
6134 (Part X)-1981	Methods of measurement of electrical characteristics of microwave tubes: Part X Crossed-field amplifier tubes
6136-1971	Basic requirements for cathode-ray tubes
6214-1971	Phosphors for cathode-ray tubes
6567-1972	Radiation protection for an X-ray tube in a protective tube-housing, operating between 10 kV and 400 kV
6568-1972	Implosion protection for TV picture tubes
6576-1972	Methods of measurements on gas-filled cold cathode indicator tubes
6577-1972	Methods of measurements on gas-filled cold cathode voltage stabilizing and voltage reference tubes
6757-1972	Dimensions for high tension cable terminations for X-ray tubes
6758-1972	Dimensions for high tension receptacles for X-ray tubes
7012-1973	Specification for X-ray tube shield
7144-1973	Methods of measurements on camera tubes
7146 (Part I)-1973	Methods of measurements on photosensitive devices: Part I Basic considerations
7146 (Part II)-1974	Methods of measurements on photosensitive devices: Part II Photo-tubes
7146 (Part III)-1974	Methods of measurements on photosensitive devices: Part III Photoconductive cells for use in the visible spectrum
7146 (Part IV)-1974	Methods of measurements on photosensitive devices: Part IV Photomultipliers
8319 (Part I)-1977	Dimensions of indicator tubes: Part I Tube type 1
8319 (Part II)-1977	Dimensions of indicator tubes: Part II Tube type 2
8319 (Part III)-1973	Dimensions of indicator tubes: Part III Tube type 3
8319 (Part IV)-1979	Dimensions of indicator tubes: Part IV Tube type 4
8441-1977	Methods of measurements on incidental X-radiation from electron tubes
9383 (Part I)-1979	Dimensions of sign indicator tubes: Part I Tube type 1
9383 (Part II)-1979	Dimensions of sign indicator tubes: Part II Tube type 2
9492-1980	Methods of measurement of RF/microwave leakage from integral circuit electron tubes

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